

UNCLASSIFIED

AD NUMBER

ADB004623

LIMITATION CHANGES

TO:

Approved for public release; distribution is unlimited.

FROM:

Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; APR 1973. Other requests shall be referred to Naval Air Systems Command, PMA-235B, Washington, DC 20360. This document contains export-controlled technical data.

AUTHORITY

ASD ltr, 27 Mar 1978

THIS PAGE IS UNCLASSIFIED

— File Copy

Powers

FTC-TR-73-18

FTC-TR-73-18

AD B004623



A-7D PITOT-STATIC SYSTEM CALIBRATION AND AIMS SYSTEM TESTS

JACK H. MARKWARDT
Captain, USAF
Performance Project
Engineer

SAMUEL G. JACKSON
Systems Project Engineer

KARL M. JONES
Major, USAF
Project Officer/Pilot

TECHNICAL REPORT No. 73-18

MAY 1973

DDC
RECEIVED
JUN 23 1973
RECEIVED
B

Distribution limited to U.S. Government agencies only
(Test and Evaluation), April 1973. Other requests for
this document must be referred to Naval Air Systems
Command, PMA-235B, Washington D.C. 20340.

AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

See Form
1473

AD No. —
DDC FILE COPY

A
F
F
I
C
I
A
L

Qualified requesters may obtain copies of this report from the Defense Documentation Center, Cameron Station, Alexandria, Va. Department of Defense contractors must be established for DDC services, or have "need to know" certified by cognizant military agency of their project or contract.

DDC release to OTS is not authorized

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related government procurement operation, the government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in anyway supplied the said drawings, specifications, or any other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

ACCESSION NO.	
NTIS	NTIS SECTION <input type="checkbox"/>
DDC	DDC SECTION <input checked="" type="checkbox"/>
SUBJECT	
AUTHORITY	
BY	
DISTRIBUTION/AVAILABILITY CODES	
ORIG	MAIL ROOM SPECIAL
B	

Do not return this copy, Retain or destroy

AIMS DISTRIBUTION (REPORT)

COPIES	TO	FOR
2	Hq ASD, WPAFB, Ohio	ENYX
1	" "	SD
4	Hq TAC, LANGLEY AFB, Va.	DOV (Major Bigham)
2	" "	LGMA
1	" "	DOO
1	" "	DRF
1	DIR MAT MGT TINKER AFB, Ok.	MMB
1	" "	MMEW
2	" "	MMBO
1	" "	MMEAF (Mr. Hodges)
1	HQ AFSC, ANDREWS AFB, Md.	SDNS
2	HQ USAF, WASH DC	XOOSL (LTC Alexander)
1	HQ AFLC, WPAFB, Ohio	MMADF
1	TFWC NELLIS AFB, NEV	TEM (LTC O'Brian)
3	HQ ESD, L. G. HANSCOM FIELD Bedford Mass 01730	DCTE
2	VSD 2-56531 (Mr. Frank McCormack)	P. O. Box 5907 Dallas, Tx. 7522
1	VSD 2-52130	" " "

FTC-TR-73-18

**A-7D PITOT-STATIC
SYSTEM CALIBRATION
AND AIMS SYSTEM TESTS**

JACK H. MARKWARDT
Captain, USAF
Performance Project
Engineer

SAMUEL G. JACKSON
Systems Project Engineer

KARL M. JONES
Major, USAF
Project Officer/Pilot

Distribution limited to U.S. Government agencies only
(Test and Evaluation), April 1973. Other requests for
this document must be referred to Naval Air Systems
Command, PMA-235B, Washington D.C. 20360.

FOREWORD

The Level 2 (Mode C) and Levels 3 through 5 AIMS tests were conducted as part of the A-7D Category II follow-on test program. The tests were conducted with A-7D AIMS modified aircraft S/N 67-14584, S/N 70-944, S/N 70-973, S/N 71-338, and S/N 71-351 between 23 February 1972 and 5 March 1973. There were 91 flights totaling 144.5 hours. The results of the Level 2 (except Mode C) and Level M tests were previously presented in a technical letter report in August 1971 (reference 1).

The authors wish to express their appreciation to Captain Robert E. Tyree and Mr. Donald J. Dowden for their assistance in preparing this report.

This evaluation was conducted under the authority of Headquarters, Air Force Systems Command as directed by AFFTC Project Directive Number 71-17, as amended by Project Directive Number 71-17D.

Foreign announcement and dissemination by the Defense Documentation Center are not authorized because of technology restrictions of the U.S. Export Control Acts as implemented by AFR 400-10.

Prepared by:

Reviewed and approved by:
27 April 1973

Jack N. Markwardt

JACK H. MARKWARDT
Captain, USAF
Performance Project Engineer

James W. Wood

JAMES W. WOOD
Colonel, USAF
Deputy Commander for Operations

Samuel G. Jackson

SAMUEL G. JACKSON
Systems Project Engineer

Howard M. Lane

HOWARD M. LANE
Brigadier General, USAF
Commander

Karl M. Jones

KARL M. JONES
Major, USAF
Project Officer/Pilot

ABSTRACT

This document contains the results, substantiating data, test techniques, and data analysis methods for the A-7D AIMS tests, Level 2 (Mode C) and Levels 3 through 5, for A-7D aircraft with boom refueling receptacles. The AIMS modification met the AIMS Levels 2 and 4 criteria. The AIMS Level 3 criterion was not met in the transonic flight regime. The Level 5 criterion was not met because the pitot-static system error was influenced by throttle setting during rapid descents at high Mach numbers, and large, rapid throttle movements caused erroneous transients in the altitude and vertical velocity indications. These transients increased pilot workload during instrument flight and caused moderate pitch oscillations at high Mach numbers with the altitude hold mode of the automatic flight control system engaged. Angle-of-attack changes caused by turbulence or pilot pitch inputs resulted in rapid, erroneous fluctuations of the airspeed indicator, altimeter, and vertical velocity indicator. Further design and testing were recommended to improve the pitot-static system in the areas that did not meet the Level 5 criterion. This document also contains the results, substantiating data, test techniques, and data analysis methods for the Levels 3 and 4 tests on an A-7E aircraft with the air refueling probe. The discussion applies to aerodynamically similar A-7D aircraft with the air refueling probe. The AIMS modification for the A-7E aircraft with W-5 and 6 air data computer (ADC) cams (designed for A-7D aircraft equipped with boom refueling receptacles) did not meet the AIMS Level 3 criterion. Further pitot-static probe design and testing were recommended to develop a system with W-5 and 6 ADC cams that would meet the Level 3 criterion.

table of contents

	<u>Page No.</u>
LIST OF ILLUSTRATIONS _____	v
LIST OF TABLES _____	vii
LIST OF ABBREVIATIONS AND SYMBOLS _____	viii
INTRODUCTION _____	1
AIMS Modification _____	2
Instrumentation _____	3
Naval Air Test Center Calibration _____	3
TEST AND EVALUATION _____	4
Level 2, Mode C _____	4
Levels 3 and 4 _____	5
Probe Model 856 W-1 and 2, Revision J _____	5
Probe Model 856 W-5 and 6 _____	6
NATC Calibration _____	9
Level 5 _____	10
Lag Investigation _____	10
Weapon Delivery Accuracy _____	11
Navigation Accuracy _____	14
Head-Up Display Accuracy _____	15
Pullup Command Evaluation _____	16
Present Position Wind Accuracy _____	17
Throttle-Induced Transients _____	18
Errors Caused by Foreign Materials _____	19
Water Ingestion _____	20
Turbulence and Angle of Attack Rate Effects _____	21
CONCLUSIONS AND RECOMMENDATIONS _____	22
A-7D Aircraft with Boom Refueling Receptacles _____	22
A-7D and A-7E Aircraft with Air Refueling Probes _____	26
DATA PLOTS AND ILLUSTRATIONS _____	27
APPENDIX - ERROR ANALYSIS AND FLIGHT LOG _____	95
Error Analysis _____	95
Overall Position Error Uncertainty _____	95
Air Data Computer Design Tolerance _____	97
Total Random System Error _____	98
Allowable Position Error in Reset _____	98
Flight Log _____	99
REFERENCES _____	101

List of Illustrations

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
1	Schematic of the Pitot-Static Line Gradients _____	27
2	Pitot-Static System Schematic _____	28
3	Revision J probe ΔH_{pc} Correction, A-7D 584 _____	29
4	Revision J Probe ΔH_{pc} Correction, A-7D 973 _____	30
5	Revision J Probe RESET Correction, A-7D 973 _____	31
6	ADC Cam Design Curves _____	32
7	Allowable Position Error in RESET _____	33
8	Revision J Probe Repeat ΔH_{pc} Correction, A-7D 584 _____	34
9	ΔH_{pc} Correction, 16 MK-82 LDGP Bombs _____	35
10	STANDBY Position Error Data, A-7D 973 _____	36
11-15	STANDBY Position Error, A-7D 973 _____	37-41
16	RESET Position Error, A-7D 973 _____	42
17-21	STANDBY Position Error, A-7D 944 _____	43-47
22	RESET Position Error, A-7D 944 _____	48
23-27	STANDBY Position Error, A-7D 338 _____	49-53
28	RESET Position Error, A-7D 338 _____	54
29-33	STANDBY Position Error, A-7D 351 _____	55-59
34	RESET Position Error, A-7D 351 _____	60
35	Representative $\Delta P/Q_{cic}$ Correction _____	61
36	Recommended Flight Manual ΔH_{pc} Correction _____	62
37	Recommended Flight Manual ΔH Correction _____	63
38	Recommended Flight Manual ΔV_{pc} Correction _____	64
39	Recommended Flight Manual ΔM_{pc} Correction _____	65
40	Levels 3 and 4 Flight Regimes, A-7D Aircraft _____	66
41	Power Approach ΔH Correction _____	67
42	Recommended Flight Manual Power Approach Correction _____	68
43	Position Error Due to Sideslip _____	69
44-45	In-Ground-Effect Position Error _____	70-71
46-47	STANDBY Position Error, A-7E 752 _____	72-73
48	A-7E Predicted RESET Correction, W-5 and 6 ADC Cams _____	74
49	A-7E Levels 3 and 4 Flight Regime, W-5 and 6 ADC Cams _____	75
50	A-7E Predicted RESET Correction, 30,000-foot Rev J ADC Cams _____	76

List of Illustrations (concluded)

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
51	A-7E Levels 3 and 4 Flight Regime, 30,000-foot Rev J ADC Cams	77
52	Pitot-Static System Error in Rapid Descent	78
53	Weapon Delivery Backup Modes Flow Diagram	79
54	Target Position Computation	80
55	Velocity Computation	81
56	Weapon Delivery Profile	82
57	Bomb Score Correction Technique	83
58-59	Weapon Delivery Test Results	84-85
60	High Altitude Nav Profile	86
61-62	Navigation Accuracy	87-88
63	HUD Position Error Corrections	89
64	Dive Recovery Chart (1)	90
65	Dive Recovery Chart (2)	91
66	Throttle-Induced Transients	92
67	Effect of Melted Plastic on ΔH_{pc}	93
68	Effect of Plastic Tape on ΔH_{pc}	94

list of tables

<u>Table No.</u>	<u>Title</u>	<u>Page No.</u>
I	Aircraft External Store Loadings _____	2
II	Altitude Correspondence _____	4
III	ADC Cam Design Corrections for the W-5 and 6 Probes _____	7
IV	ADC Cam Design Corrections for the Revision J Probes, 30,000 Feet _____	10
V	Weapon Delivery Summary _____	13
VI	HUD Altitude Corrections _____	15
VII	Pullup Command Evaluation _____	17
VIII	Wind Velocity and Direction Test _____	18
IX	A-7D Water Ingestion Test Conditions _____	21

APPENDIX

X	Variation of ΔH_{cal} , ΔH_p , and $\Delta H_{a/c}$ with Altitude _____	96
XI	Overall Position Error Uncertainty, δH_{pc} _____	96
XII	ADC Temperature Design Tolerance, ΔH_T _____	97
XIII	ADC Vibration Design Tolerance, ΔH_{vib} _____	97
XIV	ADC Design Tolerance, δH_{ADC} _____	97
XV	Total A-7D Random System Error, δH_{sys} _____	98

List of abbreviations and symbols

Item	Definition	Units
ADC	air data computer	- - -
AFCS	automatic flight control system	- - -
AGL	above ground level	- - -
AIMS	Air traffic control radar beacon system, Identification friend or foe, Mark XII identification system, System	- - -
BDU	bomb dummy unit	- - -
BFL	bomb fall line	- - -
CEA	circular error average	ft
DIG	Doppler inertial gyrocompassing	- - -
FLR	forward looking radar	- - -
FPM	flight path marker	- - -
g	acceleration due to gravity	32.17405 ft/sec ²
ΔH	aircraft position error/ADC cam correction mismatch in the RESET mode (residual position error correction of the AAU-19/A in the RESET mode)	ft
$\Delta H_{a/c}$	position error variation between different test aircraft	ft
δH_{ADC}	overall air data computer design tolerance $\delta H_{ADC}^2 = \Delta H_T^2 + \Delta H_{vib}^2 + \Delta H_{cam}^2$	ft
δH_{alt}	AAU-19/A altimeter design tolerance in the servoed (RESET) mode	ft
H_c	pressure altitude (geopotential altitude) $H_c = H_{ic} + \Delta H_{pc}$ $= H_{ir} + \Delta H$ $= H_{iH} + \Delta H_{HUD}$	ft
ΔH_{cal}	position error variation due to pacer and tower fly-by techniques	ft
ΔH_{cam}	ADC cam positioning design tolerance and cam manufacturing tolerance	ft
ΔH_H	position error correction applied by the NWDC to yield H_{iH} $H_{iH} = H_{iR} + \Delta H_H$	ft
ΔH_{HUD}	residual position error correction of the HUD	ft

<u>Item</u>	<u>Definition</u>	<u>Units</u>
H_i	indicated pressure altitude in the pneumatic (STANDBY) mode	ft
H_{ic}	indicated pressure altitude corrected for instrument error (not corrected for pressure error) in the pneumatic (STANDBY) mode	ft
H_{iH}	indicated pressure altitude on the HUD	ft
H_{ir}	indicated pressure altitude in the servoed (RESET) mode	ft
ΔH_{Lag}	correction for pitot-static system error during rapid descent	ft
ΔH_p	position error variation due to pitot-static probe design and manufacturing	ft
H_{pc}	calibrated pressure altitude	ft
ΔH_{pc}	correction for altimeter position error in the pneumatic (STANDBY) mode	ft
δH_{pc}	overall position error uncertainty between aircraft $\delta H_{pc}^2 = \Delta H_{cal}^2 + \Delta H_p^2 + \Delta H_{a/c}^2$	ft
H_R	range radar altitude	ft
ΔH_R	time dependent correlation between range radar altitude and calibrated pressure altitude	ft
ΔH_{ss}	correction to pressure altitude due to sideslip	ft
δH_{sys}	total random system error of ADC/AAU-19/A altimeter/position error uncertainty	ft
ΔH_T	ADC temperature design tolerance	ft
ΔH_{vib}	ADC vibration design tolerance	ft
HUD	head-up display	- - -
IMS	inertial measurement set	- - -
KCAS	knots calibrated airspeed	kt
kHz	kiloHertz	- - -
KIAS	knots indicated airspeed	kt
KTAS	knots true airspeed	kt
LDGP	low drag general purpose	- - -
LTV	Ling-Temco-Vought Aerospace Corporation	- - -

<u>Item</u>	<u>Definition</u>	<u>Units</u>
M	freestream (true) Mach number	- - -
M _{ic}	indicated Mach number	- - -
MIL	military rated thrust	- - -
ΔM_{pc}	correction for Machmeter position error	- - -
MSL	mean sea level	- - -
MSLP	mean sea level pressure	- - -
NATC	Naval Air Test Center	- - -
NM	nautical miles	- - -
NWDC	navigation weapon delivery computer	- - -
NWDS	navigation weapon delivery system	- - -
OFP	operational flight program	- - -
P _a	ambient atmospheric pressure	in. Hg
PA	pressure altitude	ft
PACF	Prototype Aircraft Checkout Facility	- - -
$\Delta P/Q_{cic}$	position error pressure coefficient	dimensionless
P _{sI}	static pressure corresponding to instrument corrected pressure altitude, H _{ic} , on the AAU-19/A altimeter in the pneumatic STANDBY mode	in. Hg
RAT	ram air turbine	- - -
R/D	rate of descent	fpm
REC	Rosemount Engineering Company	- - -
TLF	thrust for level flight	lb
TOL	takeoff and landing	- - -
ΔV	incremental change in velocity	kt
V _c	calibrated airspeed	kt
ΔV_{pc}	correction for airspeed position error	kt
VVI	vertical velocity indicator	- - -

INTRODUCTION

The following tests were conducted to accomplish Levels 2 through 5 of the AIMS levels of testing as specified in reference 2.

1. Flight tests to evaluate the altitude reporting correspondence (Level 2, Mode C) were accomplished with the Prototype Aircraft Checkout Facility (PACF) located at the AFFTC.
2. The pitot-static system calibrations (Levels 3 and 4) were obtained using AFFTC T-38 pacer aircraft, the tower fly-by facility, and the takeoff and landing phototheodolite facility.
3. The following tests were accomplished to satisfy the Level 5 requirements:
 - a. Lag investigation
 - b. Weapon delivery tests
 - c. Navigation accuracy tests
 - d. Head-up display (HUD) tests
 - e. Present position wind tests
 - f. Automatic flight control system (AFCS) tests
 - g. Pitot-static line water drainage tests
 - h. Turbulence and angle-of-attack rate tests

The pitot-static system error during rapid descent was evaluated during the lag investigation. The interface of the pitot-static probes/air data computer (ADC) modification with the HUD and the navigation weapon delivery system (NWDS) computer software tape was evaluated during weapon delivery in the barometric altitude bombing mode.

The effect of the revised computer software tape was also evaluated during navigation accuracy, HUD altitude-reporting, pullup command symbology, and NWDS present position wind velocity tests.

Throttle transients were evaluated during the automatic flight control system tests.

A description of the store loadings flown during the program is presented in table I.

Table I

AIRCRAFT EXTERNAL STORE LOADINGS

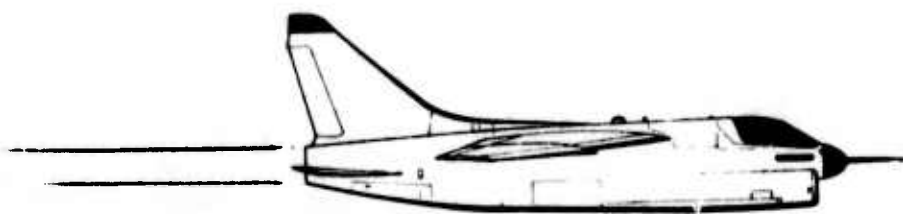
Loading No.	Description	Wing Station			Fuselage Station		Wing Station		
		1	2	3	4	5	6	7	8
1	6 pylons with MAU-12 racks	X	X	X			X	X	X
	2 Aero 3B launchers				X	X			
2	2 Aero No. 45-9534 fuel tanks			X			X		
3	2 SUU-20A/A dispensers		X					X	
	12 BDU-33B/B practice bombs		(6)					(6)	
4	2 Multiple Ejector Racks		X					X	
	12 MK-82 LDGP bombs		(6)					(6)	
5	2 Multiple Ejector Racks		X					X	
	2 Triple Ejector Racks	X							X
	16 MK-82 LDGP bombs	(2)	(6)					(6)	(2)

¹ Loadings 2 through 5 include Loading 1.
Loading 1 is referred to as the basic loading in this report.

AIMS MODIFICATION

Of the test aircraft, A-7D 584 was a pre-production aircraft and the other four aircraft were production A-7D aircraft. The first test aircraft, A-7D 973, was equipped with Rosemount Engineering Company (REC) Model 856 W-1 and 2 (Lt and Rt) Revision J aerodynamically compensating pitot-static probes. After an initial evaluation of the Revision J probes on A-7D's 584 and 973, Revision G probes were installed on A-7D 973. Due to installation problems, the pneumatic fittings were modified on the Revision G probes and the modified probes were designated REC Model 856W-5 and 6 (Lt and Rt). The REC Model 856 W-5 and 6 probes were installed on A-7D's 338, 351, 944, and 973 at fuselage station 212.4 +0.1 and water line 105.7 +0.1 with the pitot port at a 3.0 +0.5 degree nosedown attitude relative to the water line. Any further mention of pitot-static probes will refer to the REC Model 856 W-5 and 6 probes unless specifically noted.

The routing of the pitot-static lines for the AIMS-modified production aircraft was redesigned by the Oklahoma City Air Materiel Area (OCAMA), Tinker Air Force Base, Oklahoma, to insure adequate drainage and compatibility with the probe location. A negative gradient relative to the water line was provided from the probes and cockpit instruments to nosewheel well drain ports (figure 1). Additional drains were provided in the right avionics bay to trap condensation of vapors that escaped the nosewheel well drains. A schematic of the pitot-static system is presented in figure 2.



The air data computers installed were standard CP-953A/AJQ units with modified Mach and static defect cams. The ADC and the modified cams were designed and manufactured by AiResearch Manufacturing Company, Torrance, California.

The navigation weapon delivery computer (NWDC) was programmed with a modified software tape, OFP 42H, during and following the weapon delivery tests. The modified NWDC tape was supplied by Ling-Temco-Vought Aerospace Corporation (LTV), Grand Prairie, Texas.

INSTRUMENTATION

The standard cockpit altimeter and airspeed indicator were replaced with a calibrated AAU-19/A altimeter and a calibrated F-1 airspeed indicator. A one-kHz sidetone signal generator was installed in A-7D's 973 and 338, and was used to designate weapon release and to correlate lag and takeoff-and-landing (TOL) data. A C-band beacon was installed in A-7D 973 to facilitate the range radar tracking capability.

NAVAL AIR TEST CENTER CALIBRATION

This report also contains the data obtained during the pitot-static calibration on an A-7E at the Naval Air Test Center (NATC), Patuxent River, Maryland. The A-7E had a REC Model 856 W-1, Revision J probe installed on the left side and a REC Model 856 W-4, Revision A probe installed on the right side. The right probe was designed to compensate for the air refueling probe on A-7E aircraft. The USAF has A-7D aircraft in the inventory with air refueling probes. The data from the A-7E aircraft were analyzed by the AFFTC to determine if a pitot-static system with REC Model 856 W-1, Revision J and 856 W-4, Revision A probes and an ADC with cams designed for W-5 and 6 probes would meet the DOD AIMS Level 3 criterion. The data were also analyzed to determine if a pitot-static system with REC Model 856 W-1, Revision J and 856 W-4, Revision A probes and an ADC with cams designed for the 30,000-foot Revision J data would meet the DOD AIMS Level 3 criterion for A-7D aircraft with the air refueling probe.

TEST AND EVALUATION

LEVEL 2, MODE C

The mode C altitude reporting correlation was satisfactory. The AIMS system reported altitude in 100-foot increments, and no differences were noted between the aircraft indicated altitude and the transmitted altitude as received by the ground station. The results satisfied the Level 2, Mode C requirement (reference 2) and are shown in table II. The AAU-19/A altimeter indicates the same altitude as the transmitted altitude when the barocounters are set on 29.92 inches Hg. The NOTE on page 1-157 of the Flight Manual (reference 3) does not specify the required AAU-19/A altimeter barocounter setting. The following NOTE should replace the NOTE on page 1-157 of the Flight Manual: (R 1)¹

NOTE

Altitude reported to the ground station will be the same as the altitude indicated on the cockpit-mounted (barometric) altimeter with 29.92 inches Hg set on the barocounters on aircraft equipped with an AAU-19/A altimeter and RESET position selected.

Levels 2 (except Mode C) and M of the AIMS levels of testing were previously accomplished in accordance with reference 2 during the A-7D Category II Mission and Traffic Control Avionics Evaluation (reference 4).

Table II

ALTITUDE CORRESPONDENCE

Aircraft Indicated Altitude (ft)	PACF Indicated Altitude (ft:100)
4,800	048
18,100	181
20,200	202
29,600	296
34,600	346

NOTE: All aircraft indicated altitudes were obtained with the altimeter in the RESET mode and barocounters set at 29.92 inches Hg.

¹ Boldface numerals preceded by an R correspond to the recommendation numbers tabulated in the Conclusions and Recommendations section of this report.

LEVELS 3 AND 4

The airspeed calibration techniques and data reduction methods presented in reference 5 were used to obtain the level flight data.

Probe Model 866 W-1 and 2, Revision J

The data presented in figure 3 were obtained on two flights on A-7D 584 and verified the Level 1 data presented in reference 1. The fairings in figure 3 were crossplotted from data obtained on A-7D 973 and presented in figure 4. The data obtained on A-7D 584 differed from the data on A-7D 973 above 0.65 indicated Mach number. Altitude had a significant effect on position error above 0.75 indicated Mach number for both aircraft calibrations.

The altitude position error correction for the RESET mode presented in figure 5 was obtained with ADC cams designed for the 30,000-foot STANDBY position error data from the Level 1 tests. The design curve for the ADC cams is shown in figure 6. The DOD AIMS Level 3 criterion for altitude reporting systems requires that the cockpit indication be within 250 feet of the true aircraft pressure altitude (reference 2). Since random system errors are present in the cockpit indicated altitude, the allowable RESET position error must be less than 250 feet to satisfy the Level 3 criterion. The Level 3 criterion could be defined by the following expression:

$$|\Delta H + \delta H_{\text{sys}}| \leq 250 \text{ feet}$$

where

ΔH = residual position error correction for the AAU-19/A altimeter in the RESET mode (ft)

δH_{sys} = total random system error of the ADC/AAU-19/A altimeter/position error uncertainty (ft)

The error analysis presented in the appendix was conducted to determine the total random system error of the AIMS-modified A-7D aircraft and, in turn, the allowable altitude position error in the RESET mode. The results of the error analysis are presented in figure 7. The RESET position error data presented in figure 5 did not meet the Level 3 criterion due to the variation of position error with altitude above 0.75 indicated Mach number.

REC indicated that wind tunnel data for the Revision J probes on A-7D 584 were barely within their manufacturing tolerances (reference 6). A third set of Revision J probes were obtained and installed on A-7D 584. The STANDBY position error obtained on these probes is presented in figure 8. The variation of position error with altitude above 0.75 Mach number was again noted. In addition, the data did not agree with the fairings from figure 4 and indicated that probe tolerances, variations between aircraft, instrument calibrations, and airspeed calibration techniques contributed to differences noted in the data.

Store Loading Effects

Two flights were flown on A-7D 584 with 16 MK-82 LDGP bombs mounted on wing stations 1, 2, 7, and 8 with the second set of Revision J probes. Two additional flights were flown with two AERO 45-9534 fuel tanks on wing stations 3 and 6 with Revision G probes. Store effects were not evident with these store loadings (figures 9 and 18). Store loading effects at the present forward probe location are not expected with other loadings. By comparison, the store effects evident in the Level 1 tests (reference 1) for the aft probe location, fuselage station 306.0 and water line 121.0 exceeded 230 feet, varied with loading, and were, therefore, unacceptable.

Probe Model 856 W-5 and 6

The data obtained from the Revision D, E, F, G, and J probes during the Level 1 tests were re-evaluated for the slope of the position error and the effect of altitude on position error at transonic Mach numbers. The Revision G probes were selected as most likely to meet the error analysis requirements (and the DOD AIMS criteria) throughout the level flight envelope of the A-7D.

The compression sleeve fittings on the Revision J probes failed several times during the Levels 3 and 4 tests. It was recommended to REC that double flare fittings be adopted. REC made this change to the Revision G probes, realigned the mounting holes on the base plate, and re-designated the Revision G probes as Probe Model 856 W-5 and 6. The W-5 and 6 probes were aerodynamically identical to the Revision G probes.

Three flights were flown on A-7D 973 to verify the Level 1 data and to obtain additional STANDBY position error data required to design ADC cams. The position error data obtained on A-7D 973 are presented in figure 10 with fairings crossplotted from later calibrations (figure 12).

The allowable residual position error determined by the error analysis was considered in the design of ADC cams for the system with W-5 and 6 probes.

A comparison of design curves for the three sets of ADC cams tested is presented in figure 6. The ADC design correction for the W-5 and 6 probes in terms of ΔH_{pc} , ΔV_{pc} , and $\Delta P/Q_{cic}$ for 2,300, 10,000, 20,000, 30,000, and 40,000 feet is presented in table III.

A complete presentation of STANDBY and RESET position error is shown in figures 11 through 34 for A-7D's 338, 351, 944, and 973. The fairings shown on the plots of $\Delta P/Q_{cic}$ versus indicated Mach number (figures 11, 17, 23, and 29) were individually crossplotted for each aircraft to obtain the fairings on the ΔH_{pc} , ΔV_{pc} , and ΔM_{pc} plots.

The fairings of $\Delta P/Q_{cic}$ for the individual aircraft were also used to obtain a representative fairing of $\Delta P/Q_{cic}$ for the four A-7D production aircraft tested (figure 35). The representative fairing of the $\Delta P/Q_{cic}$ data was crossplotted to obtain the fairings presented in figures 36,

Table III
ADC CAM DESIGN CORRECTIONS FOR THE
W-5 AND 6 PROBES

H_{IC}	P_{s1}/P_a	P/Q_{IC}	ΔV_{pe} (kt)	ΔH_{pe} (ft)
Pressure Altitude = 2,000 ft				
0.200	0.99916	-0.0299	-1.9	-24
0.250	0.99916	-0.0190	-1.5	-23
0.300	0.99833	-0.0262	-2.4	-46
0.350	0.99749	-0.0287	-3.1	-69
0.400	0.99665	-0.0287	-3.5	-91
0.450	0.99581	-0.0278	-3.8	-113
0.500	0.99500	-0.0270	-4.1	-137
0.550	0.99415	-0.0257	-4.2	-160
0.600	0.99332	-0.0244	-4.3	-183
0.650	0.99249	-0.0229	-4.3	-205
0.700	0.99186	-0.0212	-4.2	-223
0.750	0.99290	-0.0158	-3.3	-194
0.775	0.99343	-0.0136	-3.0	-181
0.800	0.99477	-0.0100	-2.2	-143
0.825	0.99762	-0.0042	-1.0	-63
0.850	1.00234	-0.0039	0.9	64
0.875	1.01140	-0.0175	4.2	309
0.900	1.02390	-0.0343	8.3	646
Pressure Altitude = 10,000 ft				
0.250	0.99916	-0.0175	-1.2	-20
0.300	0.99833	-0.0259	-2.1	-43
0.350	0.99749	-0.0241	-2.3	-55
0.400	0.99665	-0.0286	-3.1	-86
0.450	0.99581	-0.0281	-3.4	-108
0.500	0.99500	-0.0265	-3.5	-127
0.550	0.99415	-0.0257	-3.7	-151
0.600	0.99332	-0.0244	-3.8	-171
0.650	0.99249	-0.0229	-3.9	-194
0.700	0.99186	-0.0211	-3.8	-210
0.750	0.99290	-0.0157	-3.0	-183
0.775	0.99343	-0.0135	-2.7	-170
0.800	0.99477	-0.0100	-2.0	-135
0.825	0.99762	-0.0042	-0.9	-61
0.850	1.00234	0.0039	0.8	60
0.875	1.01140	0.0175	3.8	294
0.900	1.02390	0.0342	7.6	610
Pressure Altitude = 20,000 ft				
0.450	0.99581	-0.0281	-2.8	-100
0.500	0.99500	-0.0270	-3.0	-120
0.550	0.99415	-0.0257	-3.1	-140
0.600	0.99332	-0.0243	-3.2	-160
0.650	0.99249	-0.0230	-3.3	-180
0.700	0.99186	-0.0208	-3.2	-192
0.750	0.99290	-0.0157	-2.6	-170
0.775	0.99343	-0.0135	-2.3	-157
0.800	0.99477	-0.0100	-1.7	-125
0.825	0.99762	-0.0042	-0.8	-57
0.850	1.00234	0.0039	0.7	56
0.875	1.01140	0.0176	3.3	271
0.900	1.02390	0.0342	6.6	565
Pressure Altitude = 30,000 ft				
0.550	0.99415	-0.0257	-2.6	-129
0.600	0.99332	-0.0243	-2.6	-147
0.650	0.99249	-0.0229	-2.7	-165
0.700	0.99186	-0.0211	-2.7	-179
0.750	0.99290	-0.0158	-2.1	-157
0.775	0.99343	-0.0135	-1.9	-145
0.800	0.99477	-0.0102	-1.5	-118
0.825	0.99762	-0.0042	-0.6	-52
0.850	1.00234	0.0038	0.6	51
0.875	1.01140	0.0175	2.8	249
0.900	1.02390	0.0342	5.6	520
Pressure Altitude = 35,000 ft				
0.650	0.99249	-0.0245	-2.6	-169
0.700	0.99186	-0.0211	-2.4	-172
0.750	0.99290	-0.0158	-2.0	-150
0.775	0.99343	-0.0136	-1.7	-139
0.800	0.99477	-0.0100	-1.3	-110
0.825	0.99762	-0.0042	-0.6	-50
0.850	1.00234	0.0039	0.5	50
0.875	1.01140	0.0175	2.5	238
0.900	1.02390	0.0338	5.0	491
Pressure Altitude = 40,000 ft				
0.700	0.99186	-0.0211	-2.2	-170
0.750	0.99290	-0.0157	-1.7	-148
0.775	0.99343	-0.0137	-1.6	-139
0.800	0.99477	-0.0101	-1.2	-110
0.825	0.99762	-0.0043	-0.5	-50
0.850	1.00234	0.0039	-0.5	49
0.875	1.01140	0.0175	2.3	236
0.900	1.02390	0.0341	4.5	491

38, and 39, for inclusion in the Flight Manual. A representative fairing of the RESET data is presented in figure 37. Figures 36 through 39 of this report should be inserted into the Flight Manual for use with AIMS-modified A-7D aircraft. These figures should replace figure A1-5 (sheets 1, 2, 4, and 5). (R 2)

The flight regime where the individual aircraft did not meet the Level 3 criterion is shown in figure 40. Taking the representative fairings from figure 37 as the mean for the A-7D fleet, the flight regime is shown where

the A-7D fleet should meet the requirements of the error analysis. The aircraft tested met the Level 3 criterion except in the transonic regime. DOD AIMS Document No. 153 does not require that AIMS-modified aircraft meet the Level 3 criteria in the transonic and supersonic flight envelope, but requires that the AIMS modification not degrade the aircraft position error in those flight regimes. The A-7D AIMS modification improved the system in the transonic flight regime (figure 40).

The data presented in figures 15, 21, 27, and 33 were reduced by the ΔV method (reference 5). The fairings were crossplotted from the individual $\Delta P/Q_{cic}$ fairings for each aircraft. All flight data were hand-recorded and accurate altitude readings were emphasized over airspeed. A majority of the data scatter was attributed to hand recording. The data indicated a pitot loss of approximately 2 knots on A-7D's 338 and 973 and no loss on A-7D's 351 and 944. The apparent pitot loss on A-7D 338 and 973 was attributed to the airspeed instrument calibration and the data recording method used.

Power Approach Position Error

The altitude position error correction for the RESET mode with gear down and full flaps (power approach configuration) was compared with the Flight Manual curve in figure 41. The position error, ΔH , was less than 30 feet over the power approach speed range and was as much as 130 feet less than the Flight Manual curve. Figure 42 of this report should be inserted in the Flight Manual for use with AIMS-modified A-7D aircraft. It should replace figure A1-5 (sheet 3). (R 3)

As shown in figures 12, 18, 24, and 30, the gear and flaps had negligible effect on the STANDBY position error correction, ΔH_{pc} . The curves presented in figures 36 and 38 may be used for the cruise, take-off, and power approach configurations. Figure 36 presents the representative STANDBY position error correction, ΔH_{pc} , for the four production aircraft tested. The representative airspeed position error correction over the power approach speed range was less than two knots (figure 38). The Flight Manual notes on figures A1-5 (sheets 1 and 4) state that the position error in the landing (power approach) configuration is negligible. Therefore, it was concluded that the STANDBY position error at power approach airspeeds had not changed significantly and the landing speed schedule in figure A1-7 of the Flight Manual need not be changed for AIMS-modified A-7D aircraft.

Ram Air Turbine Effects

The ram air turbine (RAT) was extended in flight on A-7D 973. The extension of the RAT did not affect position error (figures 11 through 14).

Sideslip Investigation

The sideslip investigation was conducted on A-7D 973 in the cruise configuration. The aircraft was flown in stabilized level flight at varying sideslip up to full rudder deflection. The sideslip data are presented in figure 43. No position error changes due to sideslip were observed with 50 percent rudder deflection or less and the change in position error due to sideslip with full rudder was less than 80 feet.

In-Ground-Effect Position Error

In-ground-effect position error data were obtained on A-7D 338 during ground run accelerations and in the takeoff attitude. The data were obtained with Askania phototheodolite camera coverage of takeoff accelerations. The sidetone was initiated by the pilot at predetermined airspeeds and the time of initiation was recorded on the Askania camera film for airspeed correlation. Ambient temperature, wind direction, and wind velocity were obtained from the instruments stationed near the runway. Ambient pressure was determined from the aircraft ground block data. The data obtained are presented in figures 44 and 45 for the ground run accelerations and the takeoff attitude, respectively.

These data should be compared with in-ground-effect data for the existing production system to determine if the Flight Manual takeoff, refusal, and acceleration check speeds have changed for AIMS-modified A-7D aircraft.
(R 4)

NATC Calibration

A pitot-static system calibration was performed at the NATC on A-7E USN B/N 156752. The data obtained are presented in figures 46 and 47 in terms of $\Delta P/Q_{cic}$ and ΔH_{pc} , respectively. The high altitude data were inconsistent. The fairings on the ΔH_{pc} data were crossplotted from the $\Delta P/Q_{cic}$ data. The ADC cam correction for the W-5 and 6 probes, presented in figure 5 and table III, was applied to the fairings in figure 47 to obtain the predicted RESET fairings shown in figure 48.

The predicted RESET position error for the A-7E aircraft with the W-4, Revision A right probe did not meet the Level 3 criterion. The predicted flight regime where this system would have less than 250 feet position error in the RESET mode is shown in figure 49. The error analysis was not applied to the predicted position error. It was concluded that a system with Navy-modified Revision J probes and an ADC with W-5 and 6 cams for A-7D aircraft with air refueling probes would not meet the DOD AIMS criteria.

The ADC cam correction designed for the 30,000-foot data from the Revision J probes, presented in figure 5 and table IV, was applied to the fairings in figure 47 to obtain the predicted RESET fairings shown in figure 50.

The predicted RESET data for the A-7E aircraft with the ADC cam correction designed for the Revision J probes also did not meet the requirements of the error analysis. The predicted flight regime where this system would have less than 250 feet position error in the RESET mode is shown in figure 5. The error analysis was not applied to this predicted flight regime. It was concluded that a redesign of the ADC cams would not improve the system and that a system with the Navy-modified Revision J probes was unacceptable for A-7D aircraft with the air refueling probe. A test program should be initiated to develop a modified W-6 probe designed to compensate for the air refueling probe such that a system comprised of a W-5 probe and a modified W-6 probe with corresponding W-5 and 6 ADC cams would meet all AIMS criteria for A-7D aircraft with air refueling probes.
(R 13)

Table IV
ADC CAM DESIGN CORRECTIONS FOR THE REVISION J PROBES
30,000 FEET

M_{ic}	P_{sI}/P_a	Pressure Altitude (ft)					
		Sea Level	15,000	30,000	35,000	37,500	40,000
		ΔH_{pc} (ft)	ΔH_{pc} (ft)	ΔH_{pc} (ft)	ΔH_{pc} (ft)	ΔH_{pc} (ft)	ΔH_{pc} (ft)
0.200	0.99925	-21	-----	-----	-----	-----	-----
0.300	0.99830	-20	-11	-----	-----	-----	-----
0.400	0.99692	-86	-70	-----	-----	-----	-----
0.500	0.99568	-120	-111	-83	-----	-----	-----
0.600	0.99477	-147	-133	-103	-112	-100	-101
0.700	0.99454	-152	-140	-110	-116	-107	-106
0.750	0.99750	-71	-48	-41	-54	-42	-44
0.800	1.00501	135	132	122	103	114	112
0.850	1.02230	611	566	497	464	469	467
0.875	1.05644	1,198	1,072	954	900	900	897

LEVEL 5

Lag Investigation

The lag investigation was conducted on A-7D 973 with W-5 and 6 probes. The following techniques and data reduction methods were used to obtain inflight lag from radar coverage. The test aircraft was flown in stabilized level flight at indicated altitudes of 9,000, 10,000 and 11,000 feet several times during each flight. This established a time dependent correlation between range radar altitude, H_R , and calibrated pressure altitude, H_{pc} . The aircraft was then dived from 20,000 feet at a constant dive angle with radar coverage. The bomb release tone was initiated near 12,000 feet and released as the aircraft passed an indicated RESET altitude of 10,000 feet. The indicated airspeed at tone release was recorded. Lag was determined from the following equations:

$$\Delta H_{Lag} = H_{i_r} + \Delta H - H_{pc}$$

$$H_{pc} = H_R + \Delta H_R$$

where

ΔH = residual position error in RESET at the tone release conditions

H_{i_r} = indicated pressure altitude in the servoed (RESET) mode.

ΔH_{Lag} = correction for altimeter error during rapid descent.

ΔH_R = time dependent correlation between range radar altitude and calibrated pressure altitude.

Rate of descent and radar altitude at tone release were obtained from a plot of radar altitude versus ground position with timing marks. The lag data obtained are presented in figure 52 and exhibited both Mach number and throttle setting effects. The effects were more pronounced at high transonic Mach numbers. It was concluded that spillage of high pressure air by the inlet as power was retarded and the proximity of the probes to the engine inlet caused the variation of lag with Mach number and power setting. The altitude lag was insignificant at any throttle setting with indicated Mach numbers less than 0.75. At Mach numbers above 0.80, the actual aircraft altitude should be obtained by adding ΔH_{Lag} and the altitude position error to the indicated altitude. The following NOTE should be inserted in the Flight Manual. (R 5)

NOTE

AAU-19/A SERVO (RESET) MODE

With MIL thrust, high rate of descent, and an indicated Mach number greater than 0.80, the indicated altitude may read as much as 300 feet higher than the actual aircraft altitude. For the same conditions, with IDLE thrust, the indicated altitude may read as much as 500 feet lower than the actual aircraft altitude.

Weapon Delivery Accuracy

The initial objective of the weapon delivery evaluation was to determine the effects of the revised AIMS-modified computer software tape and the modified pitot-static installation on the accuracy of the barometric altitude ranging mode of weapon delivery. During lag investigation tests, however, it was determined that the engine throttle setting effects problem could also affect barometric bombing accuracy. As a result, an additional test objective was generated.

The barometric altitude ranging mode, the third order of precedence for computed weapons delivery, was evaluated. To evaluate this mode, the forward looking radar (FLR) and radar altimeter were turned off. The weapon delivery backup mode flow diagram in figure 53 shows the reversion process the NWDS used to achieve data inputs by priority. From these inputs the NWDS continuously computed aircraft velocity in three dimen-

sions and position relative to the target as shown in figures 54 and 55 to derive a weapon delivery solution. Figure 54 also shows the velocity input order of precedence as a function of the inertial measurement set (IMS) mode selected.

Because no radar air-to-ground ranging or radar altimeter inputs were available, the barometric altitude minus target altitude was automatically used. To ensure the NWDS computer was using the proper values to compute this altitude difference, the Mean Sea Level Pressure (MSLP) method was used. This method consisted of obtaining the altimeter setting for the target area and inserting it, along with other target data, into the NWDS computer prior to takeoff.

In order to determine the magnitude of engine throttle setting effects, the weapon release condition variables were minimized. All tests were conducted at 15 and 30 degree dive angles and at 420, 450, 500, and 550 KTAS with power settings of MIL, 90 percent, and IDLE. The target elevation was 2,433 feet MSL. A target designate altitude of 8,000 feet MSL was selected for 30-degree dives and 5,000 feet MSL for 15-degree dives. The designate altitudes chosen were based on similar operational conditions used by TAC.

Once over the AFFTC bombing range, the pilot selected the Visual Normal Attack Mode and followed normal release procedures (figure 56) with one exception. In order to standardize the altitude at designate, all missions were flown using point blank aiming. This technique consisted of holding the aiming symbol and flightpath marker (FPM) on the target until reaching the designate altitudes previously mentioned. Ranging sensor inputs (barometric altitude) were used to update the weapon delivery computation only at designate and at slew (via Bullpup controller). The thumbwheel controller (RETICLE SLEW) was not used for these tests. For the engine throttle setting evaluations, BDU-33 practice bombs were used and no slewing was performed after target designation. By using this technique, only one altitude sample (at designate) was used in the weapon release solution. To evaluate the revised AIMS-modified computer software tape and pitot-static system installation, MK-82 LDGP bombs were dropped and the pilot used the Bullpup controller to keep the aiming symbol on the target until release. These tests provided an evaluation of the total systems operational capability with a more ballistically predictable weapon.

A total of 26 weapon delivery missions was flown and the results of approximately 250 bomb drops were analyzed. All of the missions flown were broken down into the following categories for analysis: aircraft serial number, type store, dive angle, true airspeed, and throttle setting.

The analysis of test results was considered to be qualitative because all aircraft tested were production configured (with the exception of a C-band beacon and a one-kHz sidetone generator on A-7D 973) and contained no onboard instrumentation recording system. In addition, the recorded magnitude and direction of aiming symbol drift at weapon release was a pilot estimate since neither aircraft possessed a HUD camera. None of the actual weapon impacts was surveyed, but were triangulated via three spotting towers, which could account for an additional error of as much as +20 feet.

Following each mission, the original bomb scores were plotted and corrected for aiming symbol drift at release as recorded by the pilot. This was accomplished by correcting the aiming symbol back to the target and then correcting the actual weapon impact the same distance and direction as the aiming symbol correction. The lateral error of the corrected scores (perpendicular to the run-in track) was then removed to establish 12 points at various distances along the aircraft groundtrack. Lateral errors were removed because barometric altitude ranging errors could theoretically cause only errors parallel to the aircraft groundtrack. An average error (long or short) was plotted for each of the three throttle settings. Figure 57 is an example of the aiming symbol correction technique used.

From the results contained in table V, it was determined that no significant bombing errors due to throttle setting effects were encountered at the three stabilized throttle settings evaluated.

Table V
WEAPON DELIVERY SUMMARY

Aircraft S/N	Store Loading ¹	Dive Angle (deg)	Airspeed (KTAS)	Bomb Scores ^{2,3} (ft)		
				Power Setting		
				MIL	90 Percent	IDLE
973	3	30	450	75	60	65
973	3	30	500	45	120	175
973	3	30	550	65	55	105
973	3	15	420	60	165	115
973	3	15	450	70	60	180
973	4	30	500	05	25	20
973	4	15	450	50	50	50
944	3	30	450	-35 ³	05	0
944	3	30	500	75	60	60
944	3	30	550	-70 ³	-35 ³	15
944	3	15	450	100	110	145
944	4	30	500	15	05	15
944	4	15	450	45	45	40

¹Store loadings are described in table I.

²Average distance from target after correcting for aiming symbol displacement at release and lateral error from the run-in heading.

³A negative average indicates an error in the direction of 12 o'clock to the target with respect to aircraft track. All of the averages except three (not including the zero point) were short of the pylon.

During evaluation of the total systems operational capability using MK-82 LDGP bombs, it was determined that satisfactory weapon delivery results could be attained using the revised AIMS-modified computer software tape and pitot-static probe installation. The scores shown in figures 58 and 59 represent the actual weapon impacts with no corrections applied. The resulting circular error averages (CEA's) represent the average bomb score. Figure 58 resulted in a CEA of 60 feet at a 15-degree dive angle and 450 KTAS. Figure 59 resulted in a CEA of 38 feet at a 30-degree dive angle and 500 KTAS.

Navigation Accuracy

Navigation accuracy evaluations were conducted at high (24,000 feet PA) and low (below 2,000 feet AGL) altitudes. Prior to the high altitude test, the pilot entered the fly-to destinations into the NWDS computer and performed a complete ground alignment on the IMS. The evaluation was conducted in the normal Doppler-Inertial Gyrocompassing (DIG) mode, and the profile in figure 60 was used. After the aircraft climbed to the test altitude the pilot followed system steering commands around the course, transmitting a tone-off data point every six minutes. At each tone-off point, the pilot recorded the time, and stored the aircraft's present position in the NWDS computer by pressing the MARK button on the computer control panel. While enroute to the next checkpoint, the pilot recorded the MARK number and corresponding coordinates. No present position updates were performed during the tests.

Before each low level mission, the pilot entered the fly-to destinations into the NWDS computer and performed a complete ground alignment on the IMS. Each test was conducted in the normal DIG mode. The low level profile was flown from Boron, California, to Winslow, Arizona, and back with tacan checkpoints at Hector, and Needles, California, and Prescott, Arizona. At each checkpoint the pilot recorded present position coordinates by using the MARK function of the NWDS computer. When depressing the MARK button the pilot recorded time and MARK number. No updates were performed during these tests.

Navigation system failures were experienced on three of the five test missions flown.

The navigation system accuracy performance was based on error limits contained in the A-7D Flight Manual, figure 1-92. The allowable navigation system error was given in terms of both expected and single flight acceptable performance in minutes per hour. This was converted to radial error in nautical miles (NM) using an average latitude of 35 degrees for all tests. The formula for conversion was as follows:

$$\text{Radial Error (NM/hr)}^2 = \left[\text{Latitude Error } \left(\frac{\text{min}}{\text{hr}} \right) \right]^2 + \left[\frac{\text{Longitude Error (min/hr)}}{\cos \text{Latitude}} \right]^2$$

This resulted in a 3.15 NM per hour limit for expected performance and a 7.9 NM per hour limit for single flight acceptable performance.

The results of the high altitude evaluation are shown in figure 61 and the accuracy was within the Flight Manual expected performance limit.

A low level test was attempted the following day; however, an inflight IMS failure precluded acquisition of any usable data. On the following low altitude navigation test (figure 61), a faulty Doppler input over Hector, California, resulted in an error limit outside the Flight Manual single flight acceptable performance requirement. It should be noted that in an operational environment an error of this type could have been rectified by performing a present position update. The results of the last two low altitude tests which are shown in figure 62 indicated that system performance was well within design limits for Flight Manual expected performance. From the results of these navigation evaluations, it was concluded that the AIMS modification did not appear to degrade the navigation capability of the aircraft in the normal DIG mode.

Head-Up Display Accuracy

The electrical signal for altitude is sent from the ADC through the NWDC to the HUD (figure 2). The airspeed signal is sent directly to the HUD from the ADC.

The HUD indicated airspeed differed from the cockpit indicated airspeed by the ΔV_{pc} correction presented in table III. The HUD indicated altitude differed from the cockpit RESET altitude by the corrections presented in table III and differed from the cockpit STANDBY altitude by the sum of the corrections presented in tables III and VI. By virtue of these corrections, the HUD indicated airspeed and altitude were more accurate than the standard flight instrument indications.

Table VI
HUD ALTITUDE CORRECTIONS

M_{ic}	Altitude Correction, ΔH_H^1				
	Sea Level	10,000 ft	20,000 ft	30,000 ft	40,000 ft
0.685	0	0	0	0	0
0.700	18	12	6	0	-18
0.750	78	52	26	0	-78
0.800	138	92	46	0	-138
0.850	198	132	66	0	-198
0.900	258	172	86	0	-258

¹The HUD altitude correction was defined by the expression

$$\Delta H_H = 400 \left(\frac{30,000 - H_{iR}}{10,000} \right) (M_{ic} - 0.685)$$

for $H_{iR} \leq 30,000$ ft and $M_{ic} \geq 0.685$

and by the expression

$$\Delta H_H = 1200 \left(\frac{30,000 - H_{iR}}{10,000} \right) (M_{ic} - 0.685)$$

for $H_{iR} \geq 30,000$ ft and $M_{ic} \geq 0.685$

and by the expression

$$\Delta H_H = 0 \text{ for } M_{ic} \leq 0.685$$

HUD accuracy tests were performed on A-7D's 973, 944, and 338. The aircraft were flown in stabilized level flight, and the HUD and cockpit instrument airspeed and altitude indications were recorded. The data were reduced by the techniques described in reference 3 and are presented in figure 63. The data uncertainty was due in part to the limited resolution of the HUD indication. HUD altitude could be read accurately to only the nearest 50 feet and HUD airspeed to only the nearest 5 knots. The data obtained from the HUD accuracy tests indicated that the NWDC corrections were being applied correctly and that the residual position error of the HUD indications was less than that of the cockpit indications.

The corrections presented in table VI were derived from the RESET mode data from A-7D 973 (figure 16). These corrections should be modified to correspond with the average RESET position error presented in figure 37. (R 6)

The following information should be inserted in the Flight Manual in the description of the position error, page A1-4 between the title and the first paragraph. (R 7)

The most accurate altitude indication is the HUD altitude; RESET altitude on the AAU-19/A altimeter is second; and the STANDBY altitude of the AAU-19/A altimeter is the least accurate. However, the HUD altitude is difficult to read accurately due to the compressed scale.

Similarly, the HUD indicated airspeed is more accurate than the indicated airspeed from the AVU-8/A airspeed-Mach indicator. The following paragraphs describe how calibrated airspeed, pressure altitude, and true Mach number are calculated.

Pullup Command Evaluation

The pullup command indication for ground avoidance displayed on the HUD was evaluated to determine the effects of the revised equations incorporated in the modified software tape OFP 42H. Dive recovery charts (figures 65 and 66) were furnished by the contractor. The charts depict the designated AGL altitude at which a pullup command indication for ground avoidance should appear as a function of aircraft dive angle and velocity. The ground avoidance routine was entered by not designating a target while diving at the ground. By not designating, the blast avoidance envelope of the pullup command signal was inhibited. A similar test was conducted during the A-7D Category II program (reference 7); the results were unacceptable in that the aircraft would have recovered above ground level on only 4 of 12 passes.

During the AIMS evaluation, 16 passes were made on a ground target in the normal attack barometric altitude ranging mode. The target elevation was increased by 2,000 feet to assure a safe escape margin. The forward looking radar and radar altimeter were turned off. The test conditions consisted of aim dive angles of 10, 15, 20, 30, 40, and 50 degrees at true airspeeds of approximately 470 and 590 knots.

The pilot stabilized the aircraft at the aim test conditions while diving on a ground target. As the anticipation cue began to move up the bomb fall line (BFL) on the HUD, the pilot transmitted a one kHz side-tone. When the pullup command (break "X") appeared on the HUD, the tone button was released and a 4g pullup in 2 seconds was initiated. C-band radar tracking and timing data provided actual aircraft position at tone off and throughout each pass.

The results of analysis are shown in table VII. Based on this single flight evaluation, the results were considered to be acceptable because final ground clearance was always positive after subtracting the 2,000 foot safety factor. It was also concluded that the throttle effect problem discovered during performance testing did not adversely affect the aircraft systems capability to provide acceptable pullup command indications to the pilot in the barometric altitude ranging mode.

Table VII

PULLUP COMMAND EVALUATION

Pass No.	Aircraft Conditions at Break "X"			Dive Recovery Chart ² Condition at Break "X" Altitude ³ (ft AGL)	Difference Between Dive Recovery Chart ² and Actual (ft)	Lowest Altitude During Recovery ³ (ft AGL)
	Velocity (ft/sec)	Dive Angle (deg)	Altitude (ft AGL)			
1	860	12	3,000	2,400	600	2,450
2	845	14	2,950	2,790	160	2,450
3 ¹	800	20	3,225	2,930	295	3,050
4 ¹	800	20	3,300	2,930	370	2,530
5	878	28	3,660	3,800	140	2,410
6 ¹	850	35	4,350	4,400	50	2,450
7	873	37	4,840	4,800	40	2,560
8	883	45	5,710	5,800	90	2,760
9	853	48	6,100	5,900	200	2,725
10	993	12	2,825	2,610	215	2,175
11	984	13	2,950	2,630	320	2,400
12	1,045	20	3,550	3,300	250	2,400
13	1,054	30	4,500	4,500	0	2,675
14	1,026	39	5,950	5,600	350	3,150
15	1,047	45	6,800	6,700	100	3,250
16	998	25	3,910	3,800	110	2,380

¹No digital data, analog data only.

²Dive recovery chart curves are shown in figures 64 and 65.

³Includes 2,000-foot safety factor.

Present Position Wind Accuracy

A wind velocity and direction test was performed to determine the effects of the revised computer software on the capability of the NWDS to compute present position wind speed and direction. Wind information was read directly from the digital data display windows of the computer control panel.

Comparisons were made by launching a reflective weather balloon and tracking it from 5,000 to 20,000 feet MSL, recording wind data every 1,000 feet. The aircraft was then flown over the same area at approximately the same time, and the pilot recorded aircraft system derived wind data every 1,000 feet.

A comparison of aircraft and tracking data indicated an average wind speed difference of 4.5 knots and an average wind direction difference of 7 degrees. The results of this single flight evaluation were acceptable. The data for this test are contained in table VIII.

Table VIII
WIND VELOCITY AND DIRECTION TEST

Altitude (ft MSL)	Aircraft Derived Wind Velocity (kt)	Balloon Wind Velocity (kt)	Difference (kt)	Aircraft Derived Wind Direction (deg true)	Balloon Wind Direction (deg true)	Difference (deg)
5,000	1	2	-1	303	280	+23
6,000	5	3	+2	100	115	-15
7,000	7	5	+2	138	140	-02
8,000	12	7	+5	162	170	-08
9,000	17	13	+4	151	180	-29
10,000	23	16	+7	156	162	-06
11,000	24	18	+6	154	155	-01
12,000	25	20	+5	161	155	+06
13,000	25	20	+5	159	155	+04
14,000	29	20	+9	162	155	+07
15,000	30	23	+7	181	175	+06
16,000	25	21	+4	180	180	0
17,00	30	22	+8	189	180	+09
18,000	28	26	+2	194	195	-01
19,000	30	26	+4	200	200	0
20,000	23	25	-2	200	200	0

Throttle-Induced Transients

It was discovered during the test program that large, rapid throttle movements caused a significant change in the altimeter and vertical velocity indications. This effect was attributed to the proximity of the probes to the engine inlet. An erroneous and transient decrease in indicated altitude and vertical velocity was observed when the throttle was moved from the thrust for level flight (TLF) setting to IDLE.

Similarly, an erroneous and transient increase in indicated altitude and vertical velocity was observed when the throttle was moved from IDLE to military rated thrust (MIL).

The throttle-induced indicated altitude transients increased in magnitude with indicated Mach number. The IDLE-to-MIL altitude transients were as great as 450 feet and the TLF-to-IDLE altitude transients were as great as -350 feet (figure 66).

The vertical velocity transients are also shown in figure 66. The altitude and vertical velocity transients significantly increased the pilot workload during instrument flight. In addition to the above

transients, airspeed changes (caused by either throttle movement or speedbrake actuation) at indicated Mach numbers above 0.60 caused the indicated altitude to change due to the slope of the position error curve in this region. The Flight Manual should be modified to include the following NOTE: (R 8)

NOTE

For AIMS-modified A-7D aircraft, large, rapid throttle movements at high Mach numbers may cause transient changes in the altitude and vertical velocity indications of as much as 450 feet and 3,500 feet per minute, respectively. For any airspeed change at high Mach numbers, the indicated altitude will change as airspeed changes due to the slope of the position error curve.

Large, rapid throttle movements at high Mach numbers with the altitude hold mode of the AFCS engaged caused roller-coaster motions of the aircraft with the normal load factor varying from 0.5 g to 2.5 g with actual change in altitude. This was caused by the pitch amplifier in the altitude hold circuitry of the AFCS trying to match the varying electrical (static pressure) signals to the original reference altitude signal. The effect was noticeable above 0.65 indicated Mach number. The Flight Manual should contain the following NOTE: (R 9)

NOTE

For AIMS-modified A-7D aircraft, large, rapid throttle movement at high Mach numbers with the altitude hold mode of the AFCS engaged may cause moderate pitch oscillations with consequent variation of altitude and normal load factor.

Errors Caused by Foreign Materials

During the Levels 3 and 4 testing on A-7D 973, a situation occurred in which the pitot heat was activated before the plastic pitot-static probe covers were removed. The melted plastic deposited on the probes produced a significant change in the position error, even though most of the plastic had been removed prior to flight. The data obtained with melted plastic on the probes are presented in figure 67 and compared with the fairings from figure 12. The resultant altitude error was as much as 120 feet.

In another instance, following a ground leak-rate check on the pitot-static system of A-7D 973, a piece of plastic tape approximately one millimeter square was left on the right probe between two static ports. The data shown in figure 68 are compared with fairings from figure 12. The data indicated a resultant altitude error as large as 580 feet.

The preceding examples show the sensitivity of position error to the presence of foreign material on the pitot-static probes. Scratches

or cracks on the probe upstream of the static port also trip the boundary layer and will cause significant errors (reference 8). Quality control procedures should be initiated to insure that the pitot-static probe covers are removed before pitot heat is activated, to insure that foreign materials deposited on the probes are removed with a suitable solvent before flight, and to consider replacement of damaged pitot-static probes. (R 10)

The following paragraph should be inserted in the Flight Manual in the description of the pitot-static system between paragraphs 2 and 3 on page 1-210. (R 11)

Aircraft modified with the AIMS pitot-static system have two symmetrically placed pitot-static probes located just aft of the FLR radome. These two probes supply the required impact and static pressures to the standard flight instruments and to the ADC.

NOTE

The pitot-static probes are extremely sensitive to damage and deposits of foreign materials at or ahead of the static ports. Scratches, nicks, burrs, and deposits on the probes may cause significant errors in indicated air-speed and altitude.

Water Ingestion

Artificial rain tests were conducted on A-7D 973 to evaluate the new pitot-static line and drain configuration. The test aircraft flew at penetration and landing pattern airspeeds behind the water spray tanker aircraft (KC-135 USAF S/N 55-3128). The water used during the test contained green dye for easy identification. The test aircraft flew near 10,000 feet in specific rain conditions (table IX) behind the tanker, climbed to 25,000 feet pressure altitude to reach sub-zero ambient temperatures after each test condition, maintained altitude for approximately 10 minutes and then descended to join up with the tanker to continue further testing. The A-7D pitot-static lines were thoroughly inspected during the postflight inspection to determine if any water was left in the system. The pitot-static drainage system was monitored during subsequent missions to determine if any residual or unnoticed water would freeze and cause a pitot-static system failure.

No pitot-static system or ADC problems occurred during any phase of the rain tests. The approximate ambient temperature at 25,000 feet was -30 degrees C. Postflight inspections revealed approximately 0.010 ounces of water at the nosewheel pitot drain during postflight inspections of the next two missions. No water was found in any other drain location and subsequent postflight inspections revealed no water in any drain. The pitot-static drainage system operated satisfactorily and no pitot-static system or ADC problems occurred during the rain tests or during subsequent missions.

Table IX

A-7D WATER INGESTION TEST CONDITIONS

Test Point	Airspeed (KTAS)	Pressure Altitude (ft)	Aircraft Separation Distance (ft)	Time in Cloud (min)	Rainfall ¹ Intensity (in./hr)
1	200	10,000	200	5	3.1
2	200	10,000	200	5	3.1
3	270	10,000	200	5	2.3
4	270	10,000	200	5	3.5

¹Rain intensity versus liquid water content (LWC)

Rainfall Condition	Intensity (in./hr)	Diameter of Drop (microns)	LWC (gm/m ³)
Clear	---	---	0.000
Fog	Trace	0.01	0.006
Mist	0.00198	0.1	0.055
Drizzle	0.0099	0.2	0.0926
Light rain	0.003937	0.45	0.138
Moderate rain	0.1588	1.0	0.277
Heavy rain	0.5940	1.5	0.833
Excessive rain	1.570	2.1	1.851
Cloud burst	3.9370	3.0	5.401

Turbulence and Angle-of-Attack Rate Effects

The AIMS modification caused undesirable pitot-static system characteristics in turbulence or with angle-of-attack change which were not present with the pre-AIMS production pitot-static system. The degraded performance was characterized by rapid, erroneous fluctuations of the airspeed indicator, altimeter, and vertical velocity indicator (VVI). Changes in angle of attack, caused by either control stick inputs or air mass turbulence, resulted in transient indications on all three instruments.

Indications caused by control stick inputs were slightly different than indications caused by air mass turbulence. The altimeter and VVI were most affected by pilot inputs, with little movement noted on the airspeed indicator. In air mass turbulence, however, the altimeter was least affected, and the airspeed indicator and VVI showed rapid fluctuations.

Altimeter indications following pilot pitch inputs were in the proper direction, i.e., an increase in angle of attack resulted in an increase in indicated altitude. Vertical velocity indication, during the same maneuvers, were in the proper direction during cruise conditions,

but showed slight reversals (as much as 200 feet per minute) during approach conditions. Vertical velocity indications were much more sensitive to these disturbances since the instrument sensed pressure rates. All transients increased in magnitude as indicated Mach number and angle of attack rate increased. The transient fluctuations in indicated altitude and vertical velocity gave the pilot false information as to the magnitude of the initial aircraft movement. When the pilot followed these initial indicated rates, he tended to overcontrol the aircraft in pitch.

Random pressure changes caused by air mass turbulence resulted in rapid fluctuations of indicated airspeed and vertical velocity which made both instruments very difficult to use during instrument flight. Very light air mass turbulence encountered during precision approaches significantly increased pilot workload required to maintain accurate glide path control. The IMS-generated vertical velocity indication and FPM as displayed on the HUD were much more accurate and reliable during these angle of attack rate transients because pressure fluctuations/pitot-static system lag did not affect these displays.

Possible causes of the undesirable indications included improper static port design, improper probe location, and insufficient static system volume. Further design effort and testing should be conducted to ensure that the AIMS modification does not degrade the pitot-static system performance from that of the pre-AIMS pitot-static system. (R 12)

CONCLUSIONS AND RECOMMENDATIONS

A-7D AIRCRAFT WITH BOOM REFUELING RECEPTACLES

The AIMS Levels of testing (2, 3, 4, and 5) have been completed for A-7D aircraft with boom receptacles for refueling. The AIMS Level 2, Mode C, and Level 4 criteria were met. The pitot-static system with REC Model 856 W-1 and 2, Revision J probes did not meet the Level 3 criterion. The pitot-static system with W-5 and 6 probes met the Level 3 criterion, although the Level 3 criterion was not met in the transonic flight regime. Level 5 deficiencies of the pitot-static system were discovered during rapid descent, throttle transients, angle-of-attack changes, and flight in air mass turbulence. The following conclusions and recommendations apply to the AIMS modification with W-5 and 6 probes.

The STANDBY position error at power approach airspeeds did not change significantly and the Flight Manual landing speed chart need not be changed for AIMS-modified A-7D aircraft.

Store loading effects were not evident for the forward probe location. The effect of extending the ram air turbine was insignificant. The effect of sideslip with up to 50 percent rudder was insignificant and the effect of sideslip with full rudder was acceptable.

The NWDS performance on the productive navigation accuracy missions was generally within the acceptable Flight Manual error limits for navigation accuracy and was not degraded by the AIMS modification. The wind velocity and direction results were acceptable. The results of the pullup command evaluation were also acceptable.

The redesigned pitot-static drainage system operated satisfactorily and no moisture-associated pitot-static system or ADC problems occurred during the rain tests or subsequent missions.

The barocounters on the AAU-19/A altimeter must be set to 29.92 inches Hg for correlation between the RESET altitude and the transmitted Mode C altitude.

1. The following NOTE should replace the NOTE on page 1-157 of the Flight Manual (page 4):

NOTE

Altitude reported to the ground station will be the same as the altitude indicated on the cockpit-mounted (barometric) altimeter with 29.92 inches Hg set on the barocounters on aircraft equipped with an AAU-19/A altimeter and RESET position selected.

The STANDBY and RESET position error for the cruise configuration of the test aircraft differed significantly from that of the existing production pitot-static system due to the AIMS modification.

2. Figures 36 through 39 of this report should be inserted in the Flight Manual for use with AIMS-modified A-7D aircraft. These figures should replace figure A1-5 (sheets 1, 2, 4, and 5) (page 7).

The position error for the RESET mode with gear down and full flaps differed significantly from that of the existing production pitot-static system.

3. Figure 42 of this report should be inserted in the Flight Manual for use with AIMS-modified A-7D aircraft. It should replace figure A1-5 (sheet 3) (page 8).

The position error in ground effect for the AIMS modification may differ from that of the existing production system.

4. The in-ground-effect position error data for the AIMS modification and the existing production system should be compared to determine if the Flight Manual takeoff, refusal, and acceleration check speeds have changed for AIMS-modified aircraft (page 9).

The lag data exhibited both Mach number and throttle setting effects. The effects of Mach number and throttle setting on lag were attributed to the proximity of the probes to the engine inlet. The variation of lag with Mach number and throttle setting did not significantly affect the barometric bombing accuracy of the aircraft for the three stabilized power settings flown. The altitude lag was insignificant at any throttle setting with indicated Mach numbers less than 0.75.

5. The following NOTE should be inserted in the Flight Manual (page 11):

NOTE

AAU-19/A SERVO (RESET) MODE

With MIL thrust, high rate of descent, and indicated Mach number greater than 0.80, the indicated altitude may read as much as 300 feet higher than the actual aircraft altitude. For the same conditions, with IDLE thrust, the indicated altitude may read as much as 500 feet lower than the actual aircraft altitude.

The ADC cam corrections and the NWDC tape corrections produce HUD airspeed and altitude indications that are more accurate than the standard flight instrument indications. The equations presented in table VI used by the NWDC were derived from the RESET data obtained on A-7D 973.

6. The corrections should be modified to correspond with the average RESET position error fairings presented in figure 37 of this report (page 16).
7. The following information should be inserted in the Flight Manual in the description of the position error, page A1-4 between the title and the first paragraph (page 16):

The most accurate altitude indication is the HUD altitude; RESET altitude on the AAU-19/A altimeter is second; and the STANDBY altitude of the AAU-19/A altimeter is the least accurate. However, the HUD altitude is difficult to read accurately, due to the compressed scale.

Similarly, the HUD indicated airspeed is more accurate than the indicated airspeed from the AVU-8/A airspeed-Mach indicator. The following paragraphs describe how calibrated airspeed, pressure altitude, and true Mach number are calculated.

Large, rapid throttle movements caused transient changes in the altitude and vertical velocity indications. The transients increased pilot workload during instrument flight.

8. The following NOTE should be inserted in the Flight Manual (page 19):

NOTE

For AIMS-modified A-7D aircraft, large, rapid throttle movements at high Mach numbers may cause transient changes in the altitude and vertical velocity indications of as much as 450 feet and 3,500 feet per minute, respectively. For any airspeed change at high Mach numbers, the indicated altitude will change as airspeed changes due to the slope of the position error curve.

Large, rapid throttle movements with the altitude hold mode of the AFCS engaged caused moderate pitch oscillations.

9. The following NOTE should be inserted in the Flight Manual (page 19):

NOTE

For AIMS modified A-7D aircraft, large, rapid throttle movements at high Mach numbers, with the altitude hold mode of the AFCS engaged may cause moderate pitch oscillations with consequent variation of altitude and normal load factor.

Deposits of foreign materials on the probes or probe damage, i.e., scratches and cracks, may seriously degrade the altitude reporting accuracy of the pitot-static system.

10. Quality control procedures should be initiated to insure that the pitot-static probe covers are removed before pitot heat is activated, that foreign materials deposited on the pitot-static probes are removed with a suitable solvent before flight, and to consider replacement of damaged pitot-static probes (page 20).
11. The following paragraph should be inserted in the Flight Manual in the description of the pitot-static system, between paragraphs 2 and 3 on page 1-210 (page 20):

Aircraft modified with the AIMS pitot-static system have two symmetrically placed pitot-static probes located just aft of the FLR radome. These two probes supply the required impact and static pressures to the standard flight instruments and to the ADC.

NOTE

The pitot-static probes are extremely sensitive to damage, and deposits of foreign materials at or ahead of the static ports. Scratches, nicks, burrs, and deposits on the probes may cause significant errors in the indicated airspeed and altitude.

Angle of attack changes, resulting from air mass turbulence or pilot pitch inputs, caused erroneous fluctuations of the airspeed indicator, altimeter, and vertical velocity indicator with the AIMS pitot-static system which were not present for the pre-AIMS production system.

12. Further design and testing should be conducted to ensure that the AIMS modification does not degrade the pitot-static system performance from that of the pre-AIMS system (page 22).

A-7D AND A-7E AIRCRAFT WITH AIR REFUELING PROBES

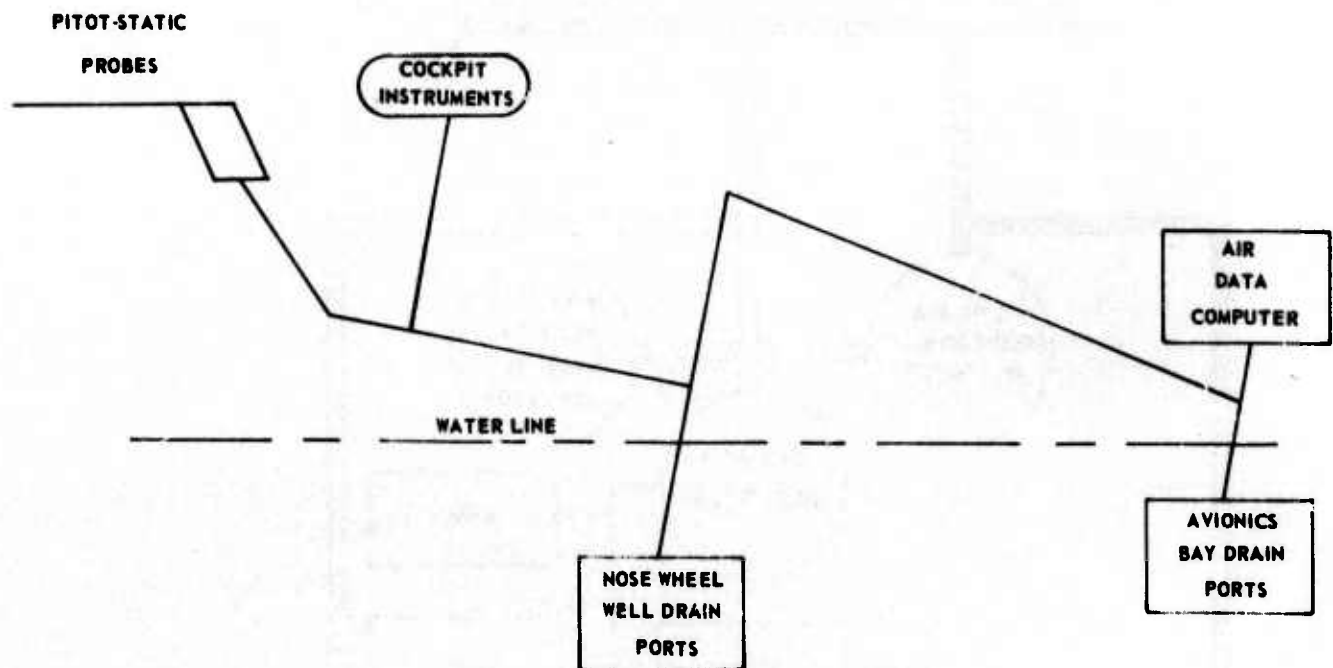
The AIMS Levels 3 and 4 testing for A-7D aircraft with the air refueling probe was conducted at NATC with an A-7E aircraft (aerodynamically identical) and have been completed.

Analysis of the NATC data indicates that a pitot-static system, for A-7D aircraft equipped with the air refueling probe, comprised of REC Model 856 W-1, Revision J and W-4, Revision A probes with the W-5 and 6 ADC cam correction would not meet the AIMS Level 3 criterion in the subsonic flight regime.

Analysis of the NATC data indicates that a pitot-static system, for A-7D aircraft equipped with an air refueling probe comprised of REC Model 856 W-1, Revision J and W-4, Revision A probes with the ADC cam correction designed for the 30,000-foot Revision J data did not meet the AIMS Level 3 criterion in the subsonic flight regime.

13. A test program should be initiated to develop a modified W-6 probe to compensate for the air refueling probe, so that a system comprised of W-5 and modified W-6 probes, with W-5 and 6 ADC cams, would meet all AIMS criteria for A-7D aircraft with the air refueling probe. (page 9).

DATA PLOTS AND ILLUSTRATIONS



NOTE: NOT TO SCALE, ANGLES REPRESENT RELATIVE SLOPES OF THE
PITOT-STATIC LINES FOR MOISTURE DRAINAGE

Figure 1 Schematic of the Pitot-Static Line Gradients

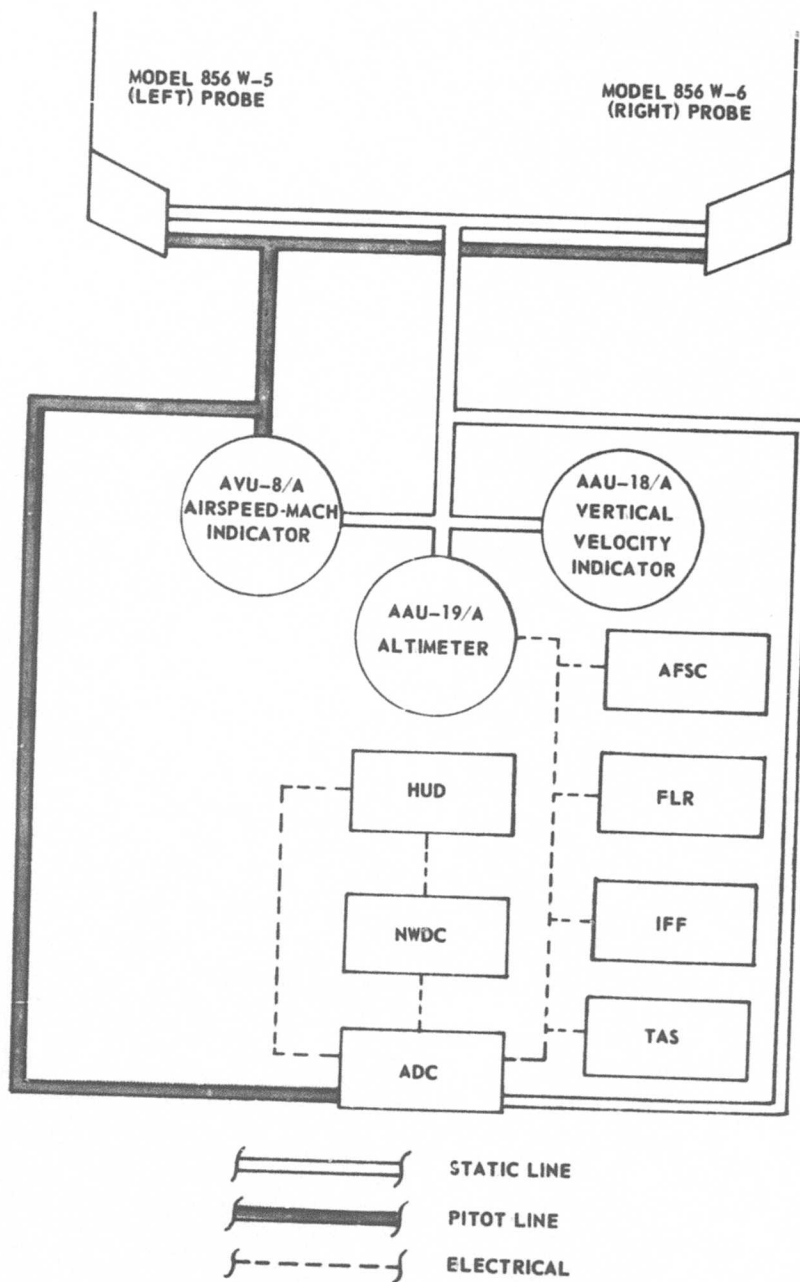


Figure 2 Pitot-Static System Schematic

A-7D USAF S/N 67-14584
REC. MODEL 856 W-162, REV J COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
A	2,300	TOWER FLY-BY	CRUISE
▽	10,000	PACE	CRUISE
○	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

- NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
2. DATA REDUCED BY THE ΔH METHOD
3. FAIRING OBTAINED FROM FIGURE 4.
4. DATA OBTAINED WITH marginally acceptable probes.

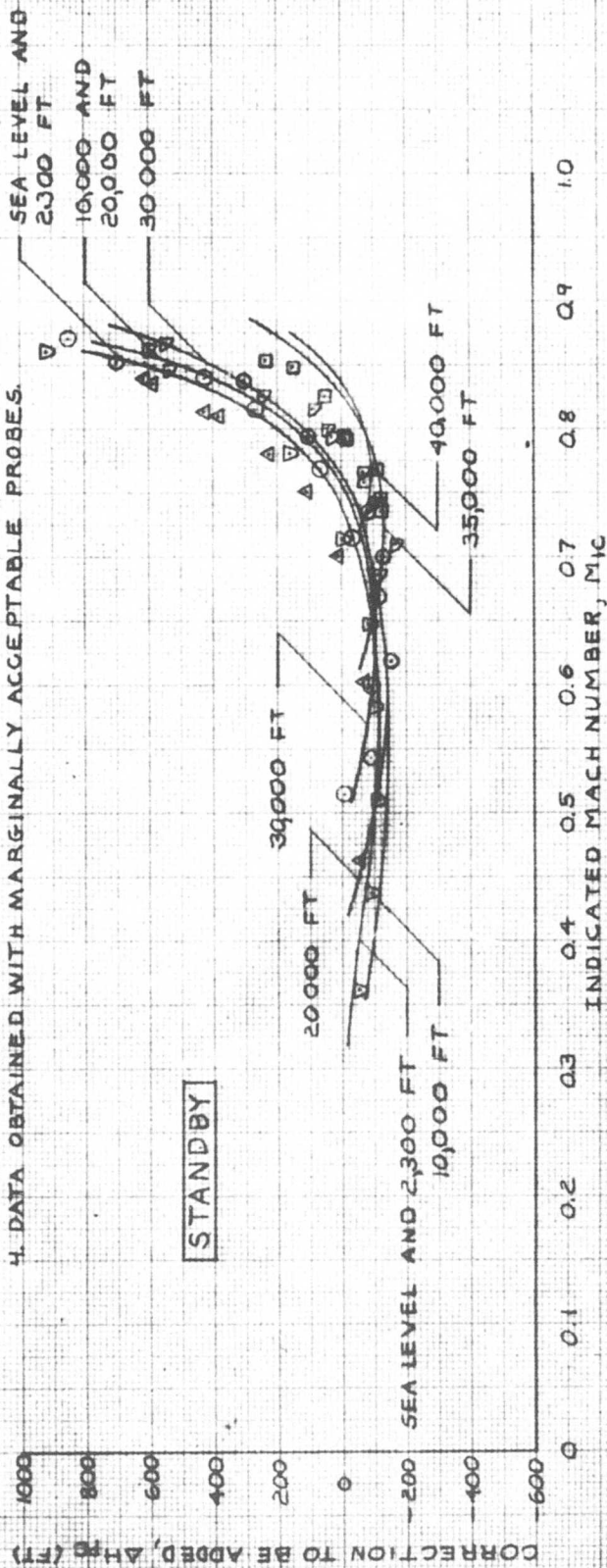


FIGURE 3 REVISION J PROBE ΔH_{PG} CORRECTION, A-7D 584

A-7D USAF S/N 70-973
REC MODEL 856W-142, REV J COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD		CONFIGURATION
		TOWER FLY-BY	TOWER FLY-BY	
△	2,300			POWER APPROACH
△	2,300			CRUISE
▽	10,000	PACE		CRUISE
◇	20,000	PACE		CRUISE
○	30,000	PACE		CRUISE
▽	35,000	PACE		CRUISE
□	40,000	PACE		CRUISE

NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
2. DATA OBTAINED BY THE AH METHOD

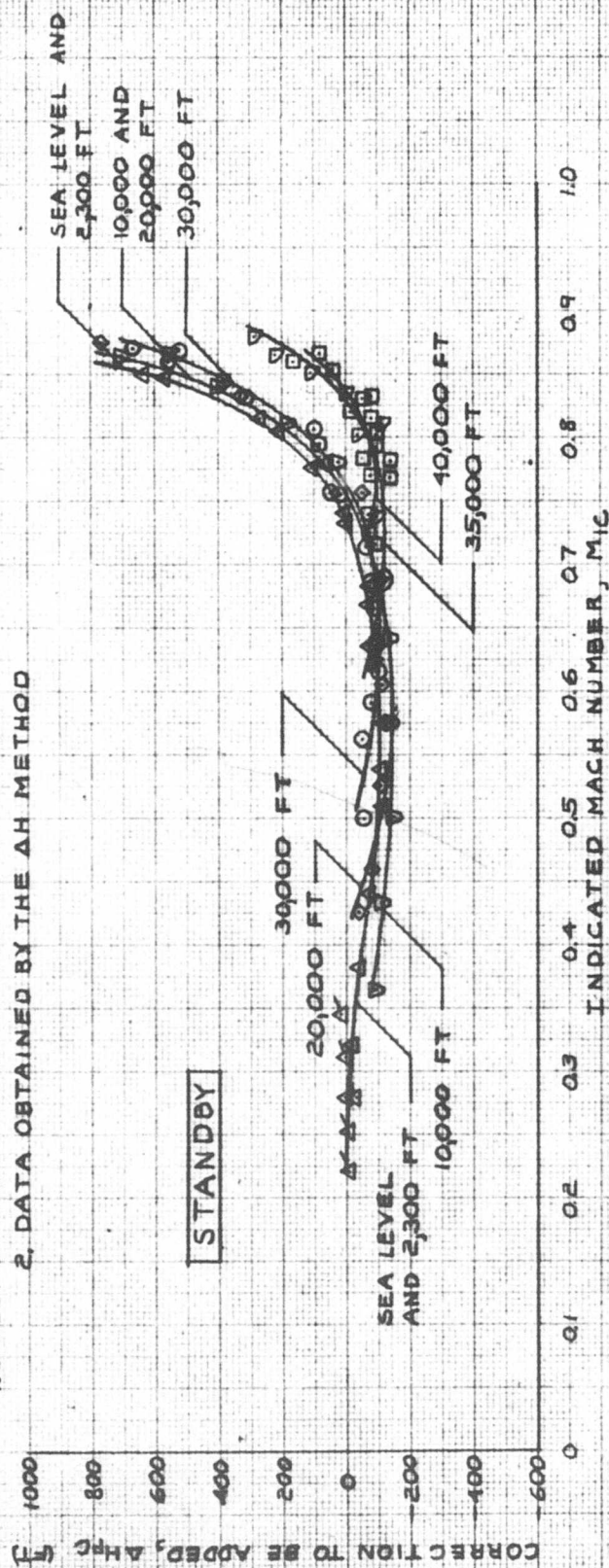


FIGURE 4 REVISION J PROBE ΔH_{FC} CORRECTION, A-7D 973

A-7D USAF S/N 70-973
REC MODEL 856 W-1E2 REV J COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
A	2,300	TOWER FLY-BY	POWER APPROACH
Δ	2,300	TOWER FLY-BY	CRUISE
▽	10,000	PACE	CRUISE
◇	20,000	PACE	CRUISE
○	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

NOTES: 1. AAU-19/A IN RESET
2. DATA OBTAINED BY THE ΔH METHOD

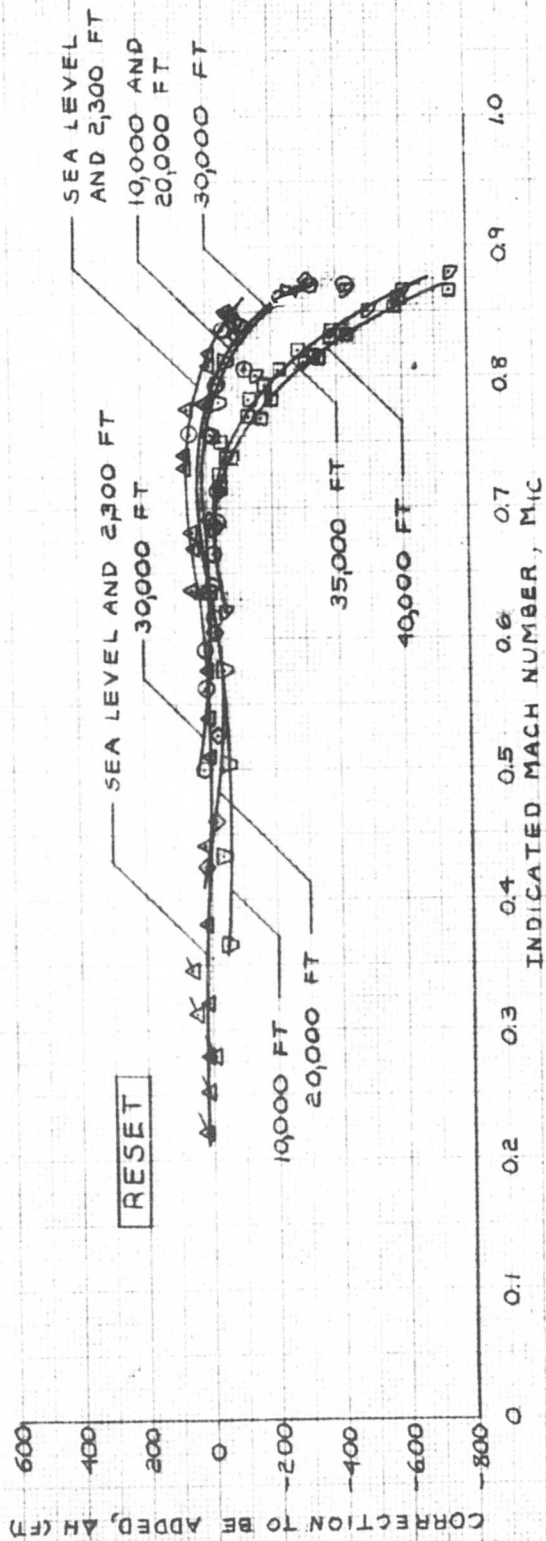


FIGURE 5 REVISION J PROBE RESET CORRECTION, A-7D 973

ADC CAM CORRECTION CURVES

SYMBOL	TEST AIRCRAFT	REC PROBE MODEL
V	A-7D USAF S/N 67-14584	856 W-142, REV J
O	A-7D USAF S/N 67-14584	856 W-142, REV J
O	A-7D USAF S/N 70-973	856 W-546

NOTE DATA POINTS REPRESENT THE VALUES SPECIFIED IN THE AIRESEARCH CONTRACTS.

DESIGNED FOR THE REV J 10,000 FT DATA (REFERENCE 1)

DESIGNED FOR THE REV J 30,000 FT DATA (REFERENCE 1)

DESIGNED FOR THE W-546 35,000 FT DATA PRESENTED IN FIGURE 10

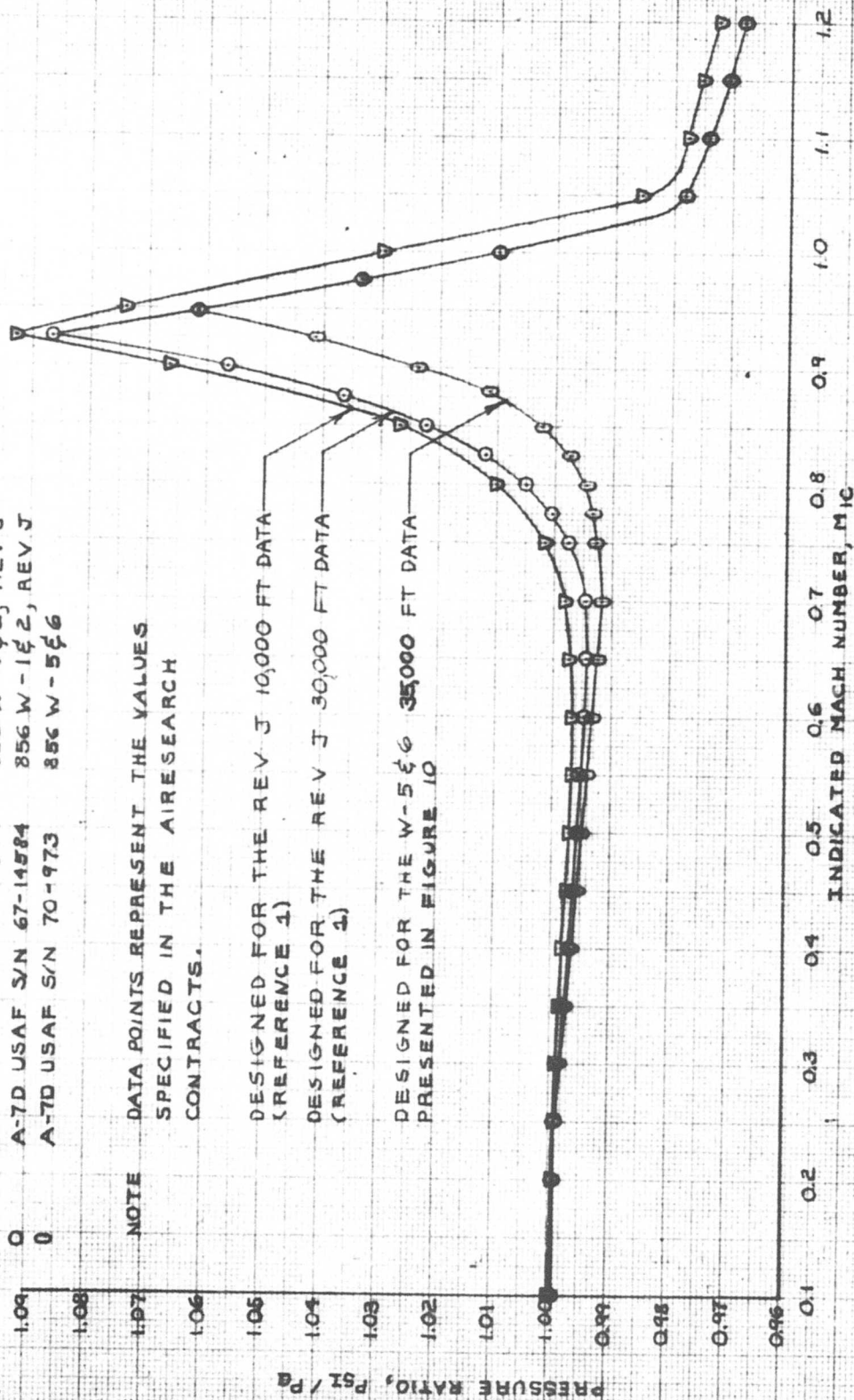


FIGURE 6. A7D CAM DESIGN CURVES

ALT (FT)	CASE 1		CASE 2	
	ADC OPERATING ENVIRONMENTAL TEMPERATURE (DEG C)	$\Delta H_{a/c}$ (FT)	ADC OPERATING ENVIRONMENTAL TEMPERATURE (DEG C)	A-7D ESTIMATED $\Delta H_{a/c}$ (FT)
2300	10 TO 50	0	20	85
10000	10 TO 50	0	5	70
20000	10 TO 50	0	-10	50
30000	10 TO 50	0	-25	25
40000	10 TO 50	0	-30	0

NOTE: DOD AIMS LEVEL 3 CRITERIA
REQUIRES THAT THE ABSOLUTE
VALUE OF ($\Delta H \pm \delta H_{SYS}$) BE
BE LESS THAN 250 FT.

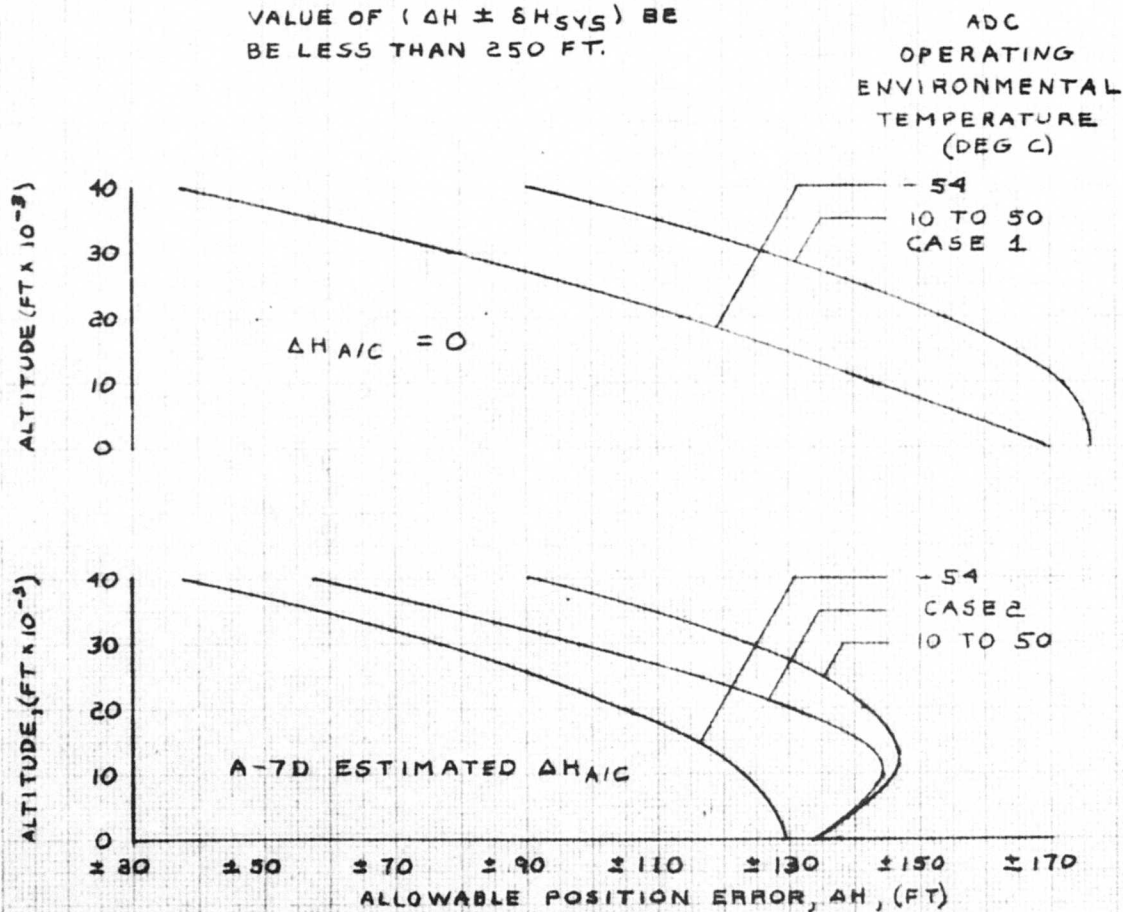


FIGURE 7 ALLOWABLE POSITION ERROR IN RESET

A-7D USAF S/N 67-14584
REC MODEL 856W-142, REV J COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
A	2,300	TOWER FLY-BY	POWER APPROACH
Δ	2,300	TOWER FLY-BY	CRUISE
V	10,000	PACE	CRUISE
O	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

NOTES: 1. AAU-19/A ALTIMETER IN STANDBY

2. DATA OBTAINED BY THE ΔH METHOD

3. FAIRING OBTAINED FROM FIGURE 4.

4. DATA OBTAINED WITH THIRD SET OF REV J PROBES

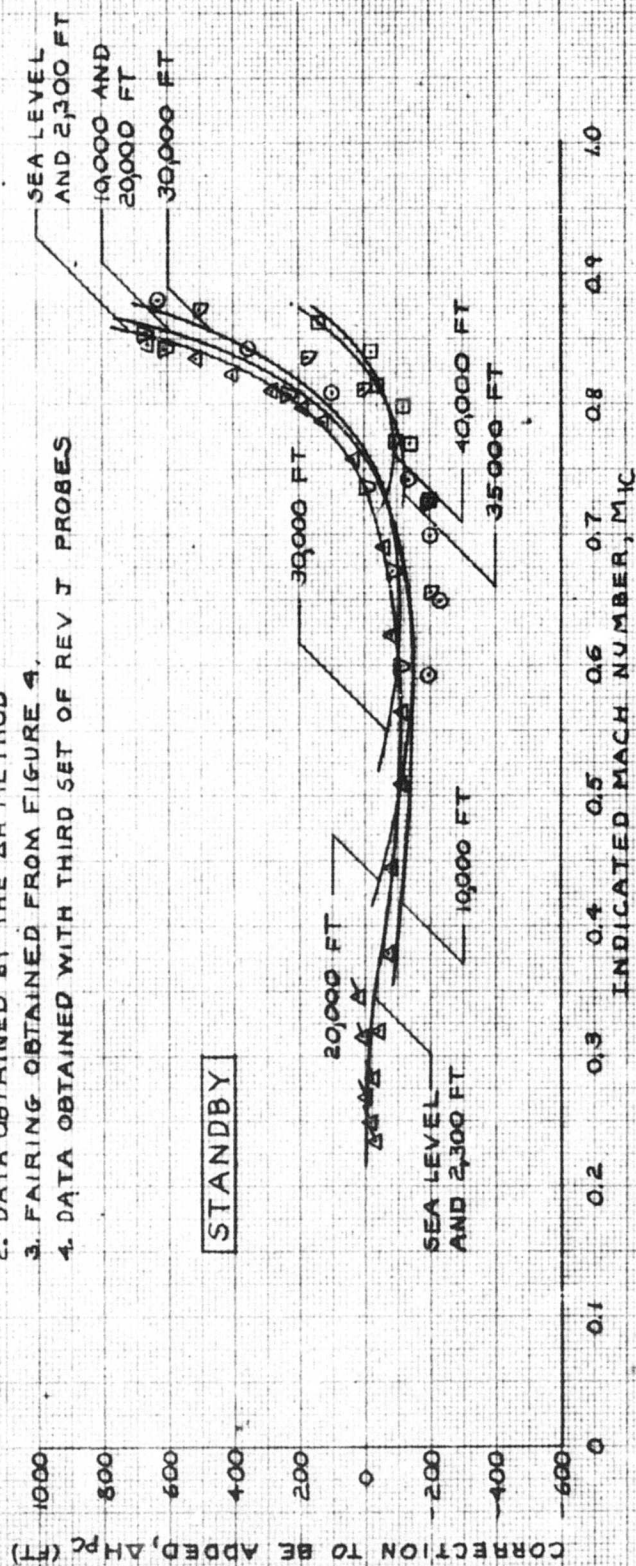


FIGURE 8 REVISION J PROBE REPEAT Δh_{pc} CORRECTION, A-7D 584

A-7D USAF S/N 67-14584
 REC MODEL 856 W-162, REV J COMPENSATING PITOT-STATIC PROBES
 LOADING 5: BASIC + 16 MARK 82 LDGP BOMBS

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
Δ	2,300	TOWER FLY-BY	CRUISE
∇	10,000	PACE	POWER APPROACH
∇	10,000	PACE	CRUISE
\circ	15,000	PACE	CRUISE

- NOTES: 1. AAU-19A ALTIMETER IN STANDBY
 2. DATA OBTAINED BY THE ΔH METHOD
 3. FAIRING OBTAINED FROM FIGURE 4.

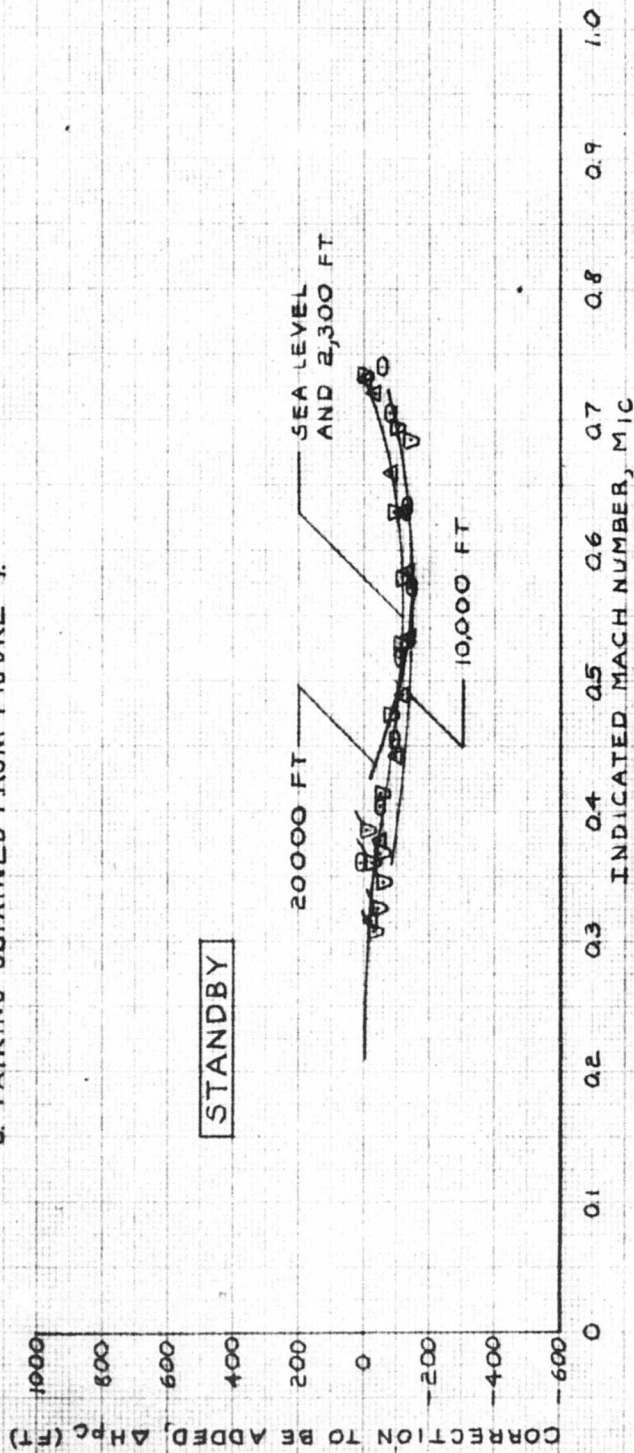


FIGURE 9 ΔH_{pc} CORRECTION, 16 MK 82 LDGP BOMBS

A-7D USAF S/N 70-973
REC MODEL 856W-546 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
△	2,300	TOWER FLY-BY	POWER APPROACH
△	2,300	TOWER FLY-BY	CRUISE
▽	10,000	PACE	POWER APPROACH
▽	10,000	PACE	CRUISE
○	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

- NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
2. DATA OBTAINED BY THE ΔH METHOD
3. FAIRINGS CROSSPLOTTER FROM FIGURE 11
4. DATA WAS USED TO DESIGN THE W-546 ADC CAMS

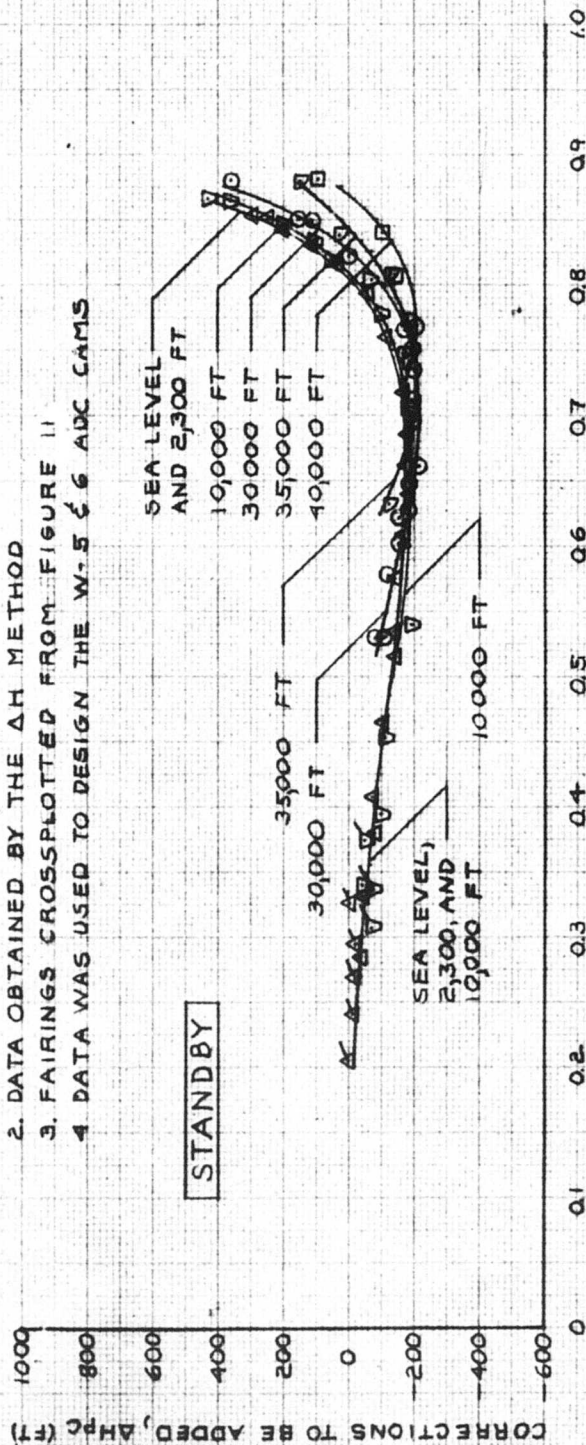


FIGURE 10. STANDBY POSITION ERROR DATA, A-7D 973

A-7D USAF S/N 70-973
REC MODEL 856W-546 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
△	2,300	TOWER FLY-BY	POWER APPROACH
△	2,300	TOWER FLY-BY	CRUISE
▽	10,000	PACE	POWER APPROACH
▽	10,000	PACE	CRUISE
○	30,000	PACE	CRUISE
●	30,000	PACE	RAT EXTENDED
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
2. DATA OBTAINED BY THE ΔH METHOD

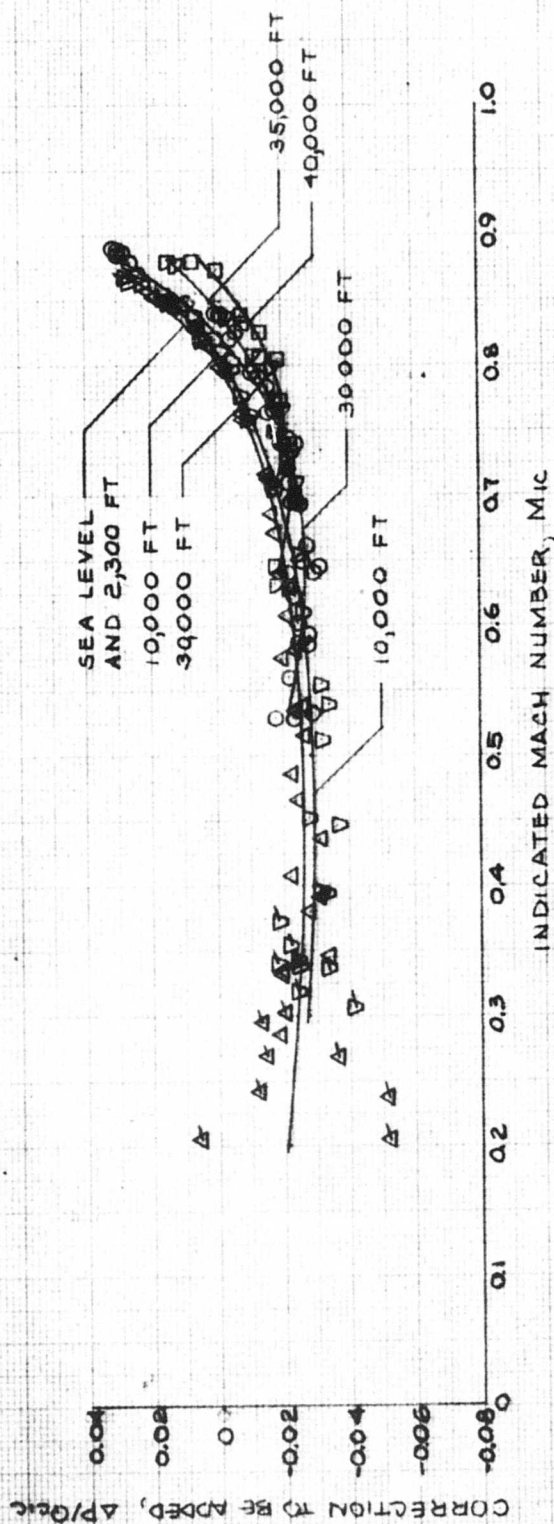


FIGURE 11 STANDBY POSITION ERROR, A-7D 973

A-7D USAF S/N 70-973
REC MODEL 856 W-566 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
Δ	2,300	TOWER FLY-BY	POWER APPROACH
Δ	2,300	TOWER FLY-BY	CRUISE
∇	10,000	PACE	POWER APPROACH
∇	10,000	PACE	CRUISE
\circ	30,000	PACE	CRUISE
\bullet	30,000	PACE	RAT EXTENDED
∇	35,000	PACE	CRUISE
\square	40,000	PACE	CRUISE

CORRECTION TO BE ADDED, ΔH_{PC} (FT)

- NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
2. DATA OBTAINED BY THE ΔH METHOD
3. FAIRINGS CROSSPLOTTED FROM FIGURE 11.

STANDBY

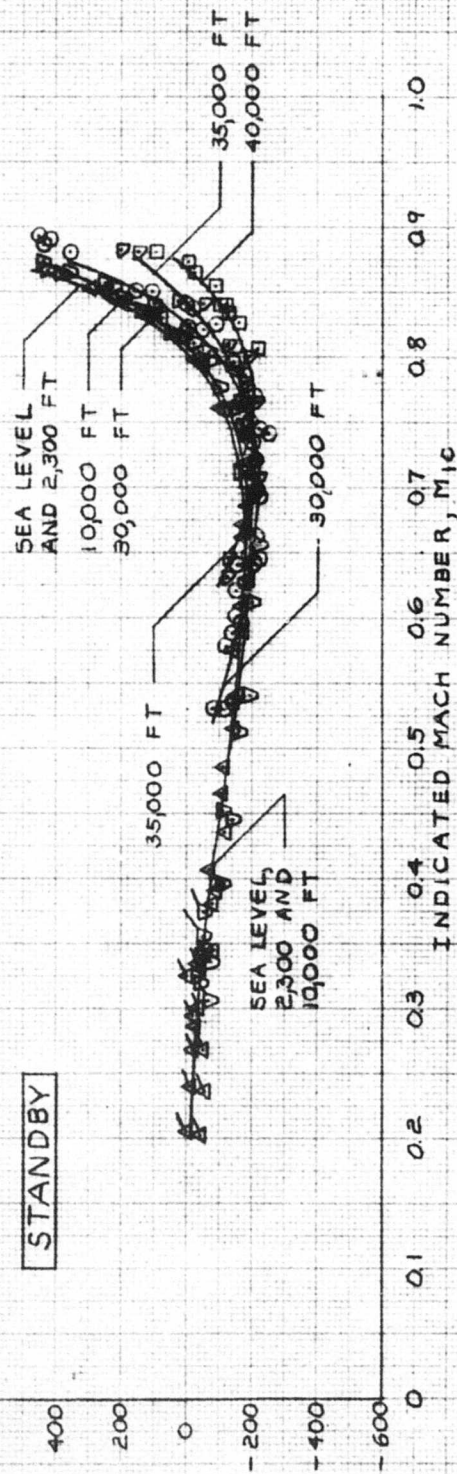


FIGURE 12. STANDBY POSITION ERROR, A-7D 973

A-7D USAF S/N 70-973
 REC MODEL 856 W-546 COMPENSATING PITOT-STATIC PROBES
 LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
A	2,300	TOWER FLY-BY	POWER APPROACH
A	2,300	TOWER FLY-BY	CRUISE
V	10,000	PACE	POWER APPROACH
V	10,000	PACE	CRUISE
O	30,000	PACE	CRUISE
●	30,000	PACE	RAT EXTENDED
V	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

CORRECTION TO BE ADDED, ΔM_{PC}

NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
 2. DATA OBTAINED BY THE ΔH METHOD
 3. FAIRINGS CROSS PLOTTED FROM FIGURE 11

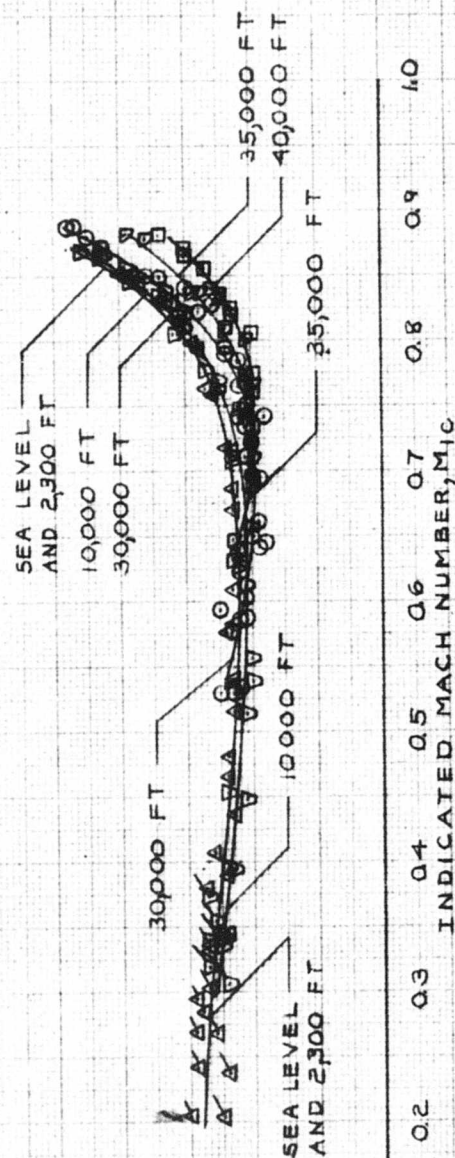


FIGURE 13 STANDBY POSITION ERROR, A-7D 973

A-7D USAF S/N 70-973
REC MODEL 856 W-566 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE/FT	METHOD	CONFIGURATION
A'	2,300	TOWER FLY-BY	POWER APPROACH
A	2,300	TOWER FLY-BY	CRUISE
V	10,000	PACE	POWER APPROACH
V	10,000	PACE	CRUISE
V	30,000	PACE	CRUISE
O	30,000	PACE	RAT EXTENDED
●	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

CORRECTION TO BE ADDED, ΔV/C (KT)

NOTES: 1. AAU-19/A ALTIMETER IN STANDBY

2. DATA OBTAINED BY THE AH METHOD

3. FAIRINGS WERE CROSSPLOTTED FROM FIGURE 11.

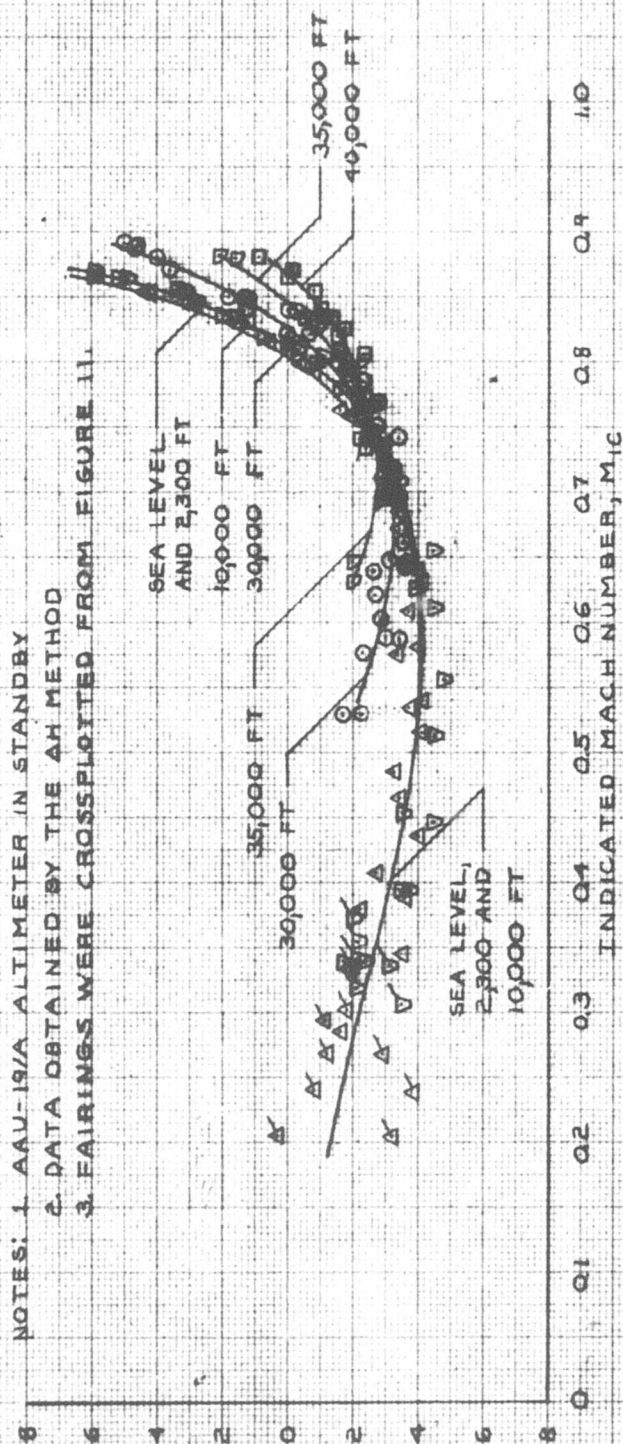


FIGURE 14 STANDBY POSITION ERROR, A-7D

A-7D USAF S/N 70-973
REC MODEL 856 W-546 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	CONFIGURATION POWER APPROACH
▽	10,000	CRUISE
▽	10,000	CRUISE
○	30,000	CRUISE
▽	35,000	CRUISE
□	40,000	CRUISE

- NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
2. DATA OBTAINED WITH T-38 PACE BY THE ΔV METHOD
3. FAIRINGS OBTAINED FROM FIGURE 14

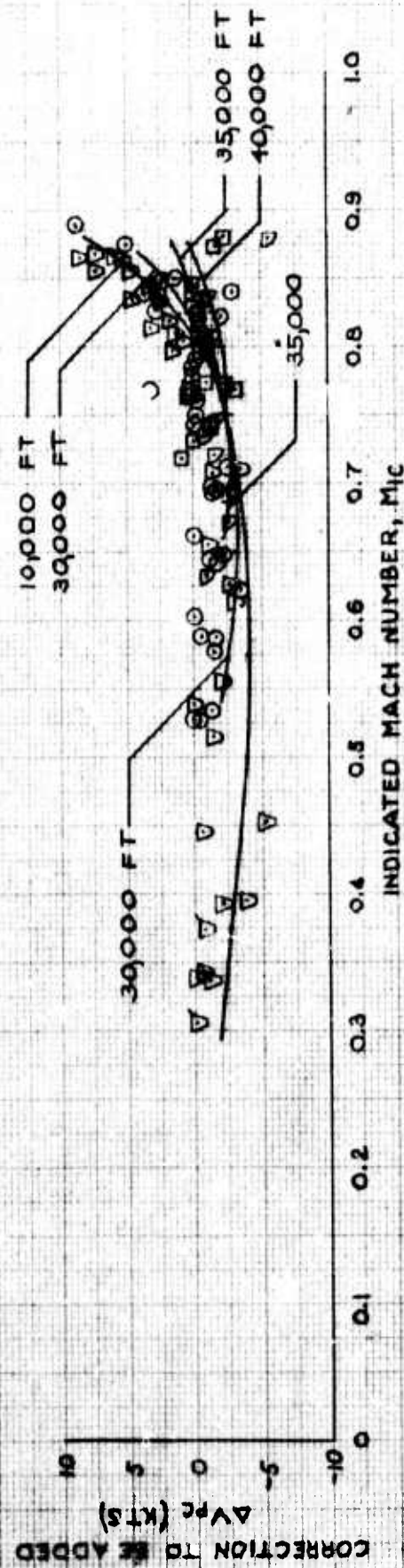


FIGURE 15 STANDBY POSITION ERROR, A-7D 973

A-7D USAF S/N 70-973
REC MODEL 856W-566 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
A	2,300	TOWER FLY-BY	POWER APPROACH
Δ	2,300	TOWER FLY-BY	CRUISE
▽	10,000	PACE	POWER APPROACH
∇	10,000	PACE	CRUISE
○	30,000	PACE	RAT EXTENDED
●	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

NOTES: 1. AAU-19/A ALTIMETER IN RESET
2. DATA OBTAINED BY THE ΔH METHOD

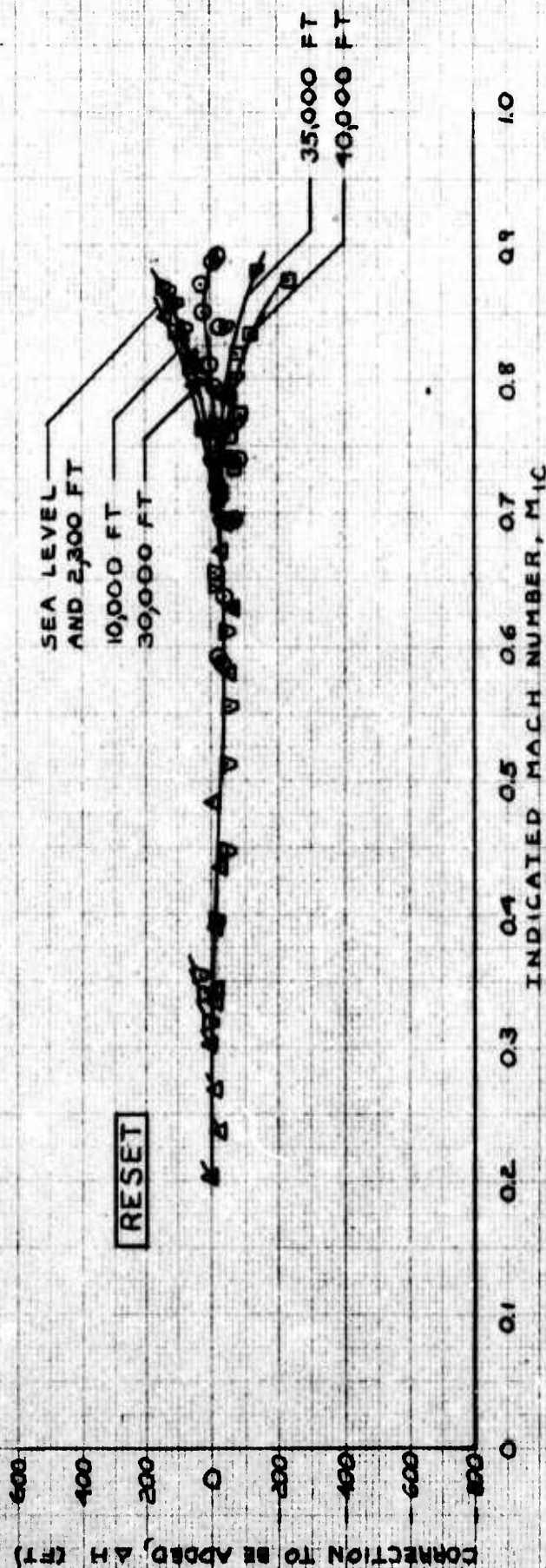


FIGURE 16 RESET POSITION ERROR, A-7D 973

A-7D USAF S/N 70-944
 REC MODEL 856W-5+6 COMPENSATING PITOT STATIC PROBES
 LOADING 2 : BASIC + 2 300 GAL TANKS

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
△	2,300	TOWER FLY-BY	POWER APPROACH
△	2,300	TOWER FLY-BY	CRUISE
▽	10,000	PACE	POWER APPROACH
▽	10,000	PACE	CRUISE
○	30,000	PACE	CRUISE
▽	36,000	PACE	CRUISE
□	40,000	PACE	CRUISE

- NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
 2. DATA OBTAINED BY THE ΔH METHOD
 3. SHADED SYMBOLS ARE DATA OBTAINED WITH LOADING 1

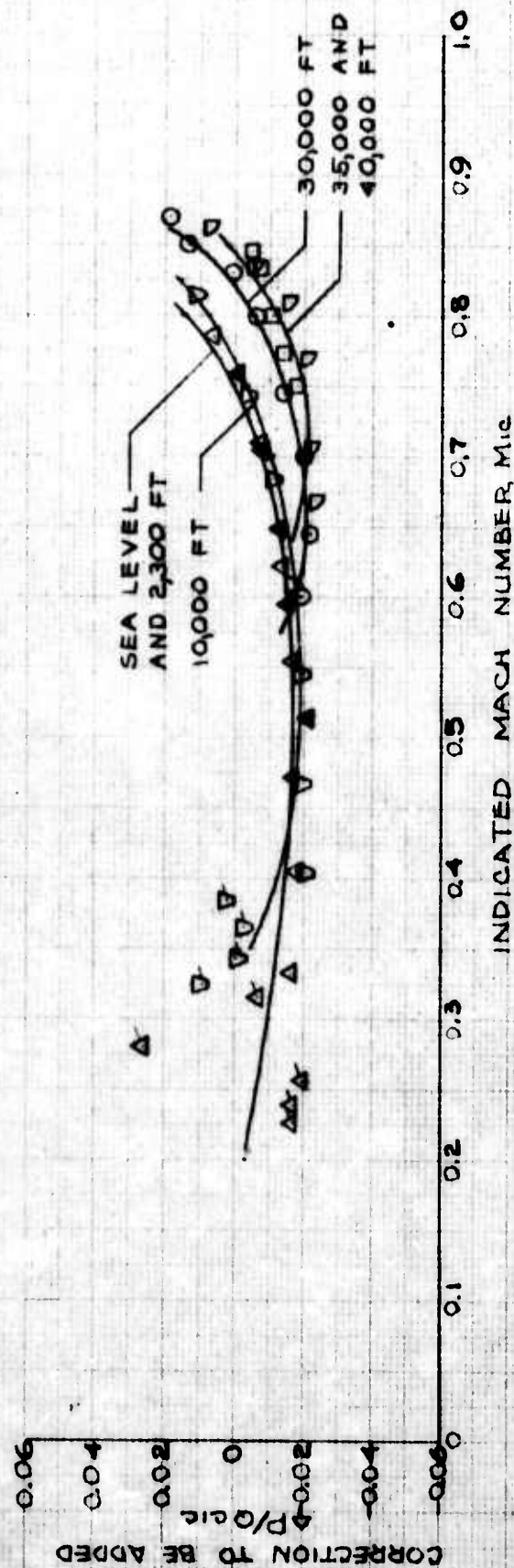


FIGURE 17 STANDBY POSITION ERROR, A-7D 944

A-7D USAF S/N 70-944
REC MODEL 856W-566 COMPENSATING PITOT-STATIC PROBES
LOADING 2.; BASIC + 2 300 GAL TANKS

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
Δ	2,300	TOWER FLY-BY	POWER APPROACH
Δ	2,300	TOWER FLY-BY	CRUISE
∇	10,000	PACE	POWER APPROACH
∇	10,000	PACE	CRUISE
\square	30,000	PACE	CRUISE
∇	35,000	PACE	CRUISE
\square	40,000	PACE	CRUISE

NOTES: 1. AAU-19/A ALTIMETER IN STANDBY

2. DATA OBTAINED BY THE Δ H METHOD

3. SHADED SYMBOLS ARE DATA OBTAINED WITH LOADING 1.

4. FAIRINGS WERE GROSS PLOTTED FROM FIGURE 17

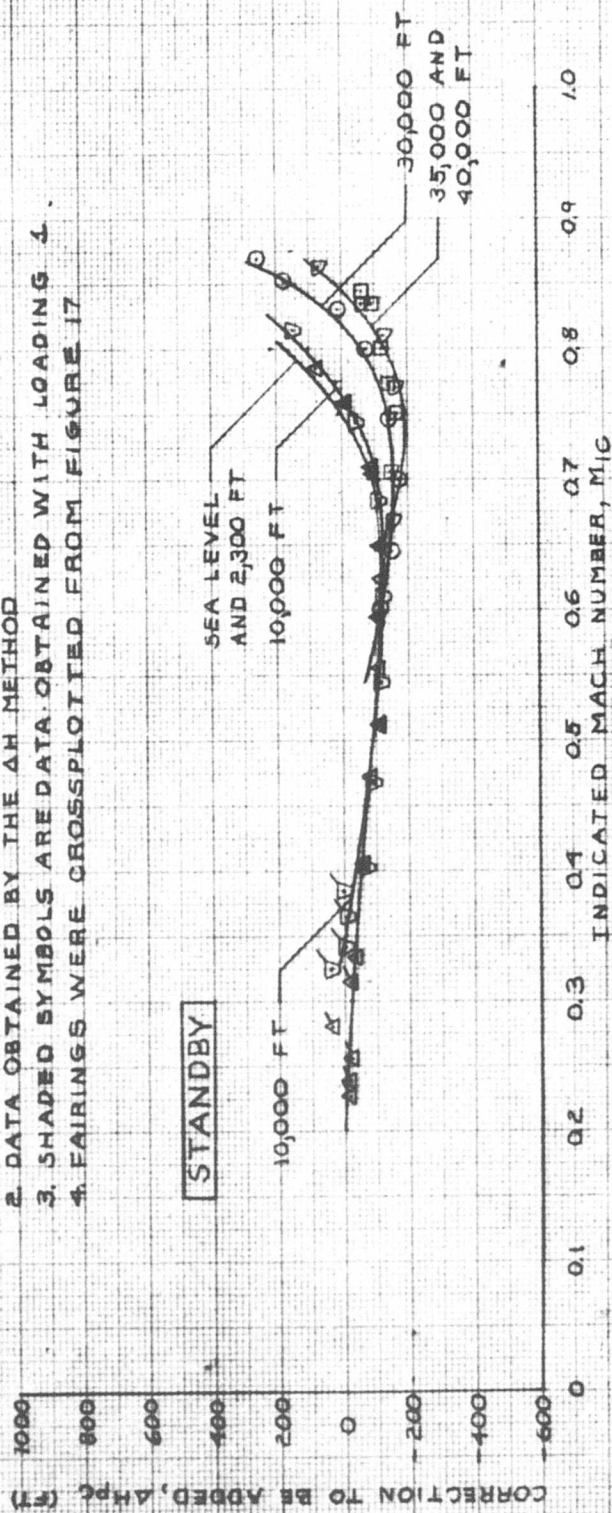


FIGURE 18. STANDBY POSITION ERROR, A-7D 944

A-7D USAF S/N 70-944
REC MODEL 856W-5 & 6 COMPENSATING PITOT STATIC PROBES
LOADING 2: BASIC + 2 300 GAL TANKS

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
△	2,300	TOWER FLY-BY	POWER APPROACH
△	2,300	TOWER FLY-BY	CRUISE
▽	10,000	PACE	POWER APPROACH
▽	10,000	PACE	CRUISE
○	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

- NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
2. DATA WERE OBTAINED BY THE AH METHOD.
3. SHADED SYMBOLS ARE DATA OBTAINED WITH LOADING 1
4. FAIRINGS WERE CROSSPLOTED FROM FIGURE 17

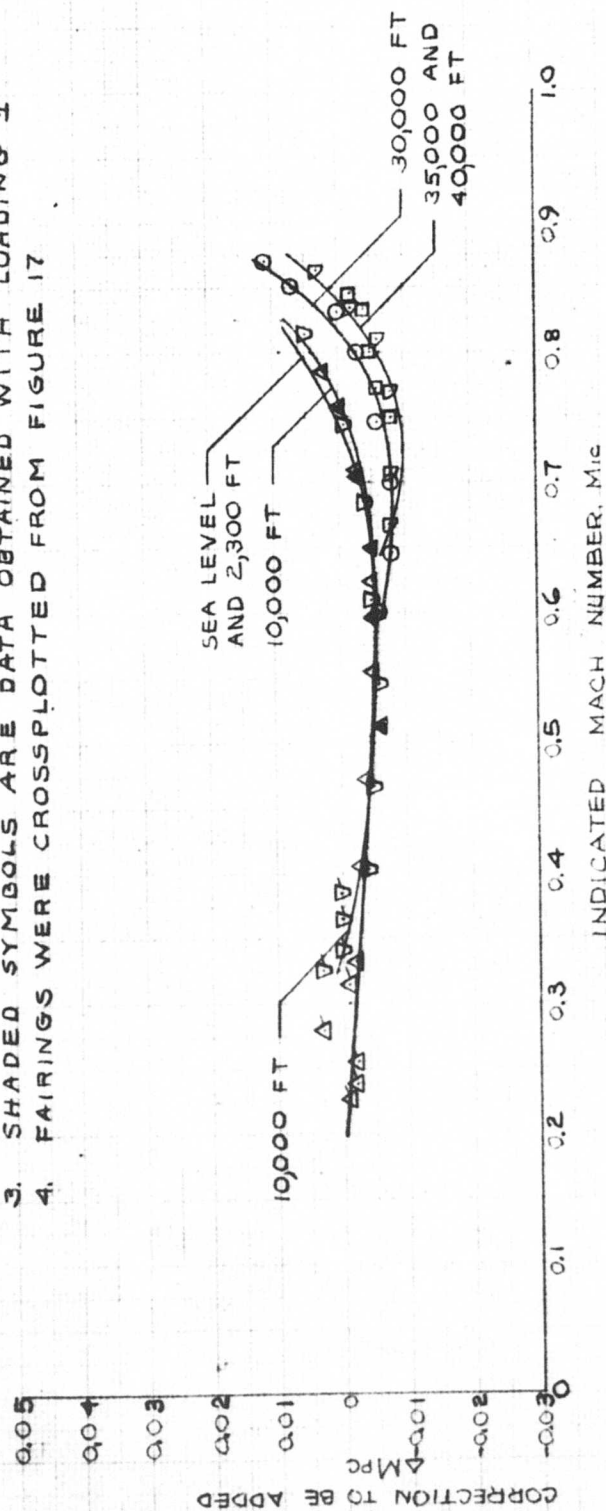


FIGURE 19 STANDBY POSITION ERROR, A-7D 944

A-7D USAF S/N 70-944
 REC MODEL 856W-5#6 COMPENSATING PITOT STATIC PROBES
 LOADING 2: BASIC + 2 300 GAL TANKS

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
△	2,300	TOWER FLY-BY	POWER APPROACH
△	2,300	TOWER FLY-BY	CRUISE
▽	10,000	PACE	POWER APPROACH
▽	10,000	PACE	CRUISE
○	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

- NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
 2. DATA WERE OBTAINED BY THE ΔH METHOD
 3. SHADED SYMBOLS ARE DATA OBTAINED WITH LOADING 1
 4. FAIRINGS WERE CROSSPLOTTED FROM FIGURE 17.

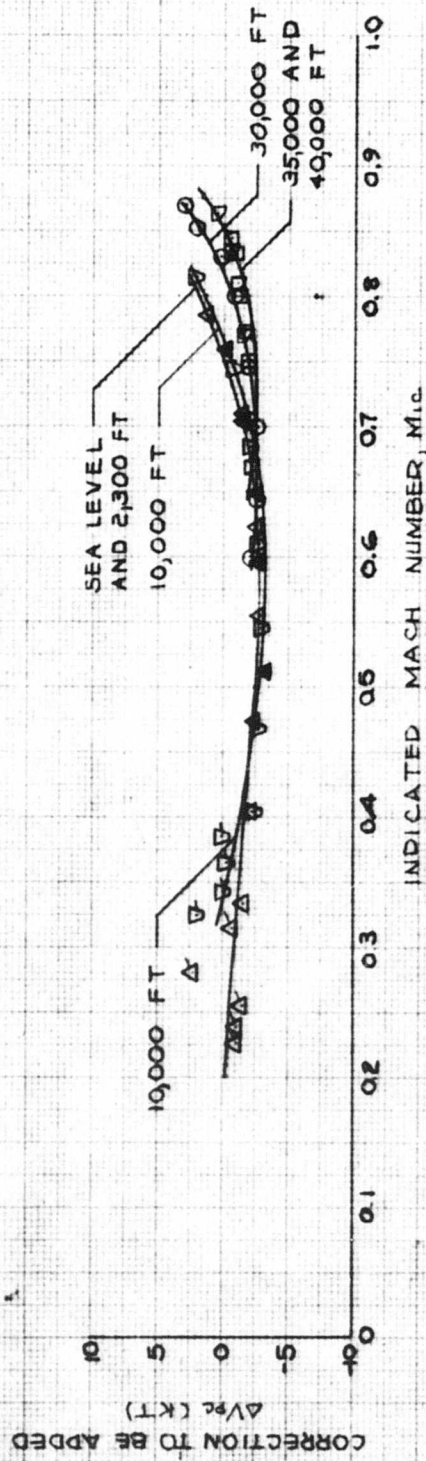


FIGURE 20 STANDBY POSITION ERROR, A-7D 944

A-7D USAF S/N 70-944
REC MODEL 856W-546 COMPENSATING PITOT-STATIC PROBES
LOADING 2

SYMBOL	ALTITUDE (FT)	CONFIGURATION
∇	10,000	POWER APPROACH
∇	10,000	CRUISE
\circ	30,000	CRUISE
∇	35,000	CRUISE
\square	40,000	CRUISE

- NOTES 1. AAU-19/A ALTIMETER IN STANDBY.
2. DATA WERE OBTAINED WITH T-38 PACE BY THE ΔV METHOD
3. FAIRINGS WERE OBTAINED FROM FIGURE 20.

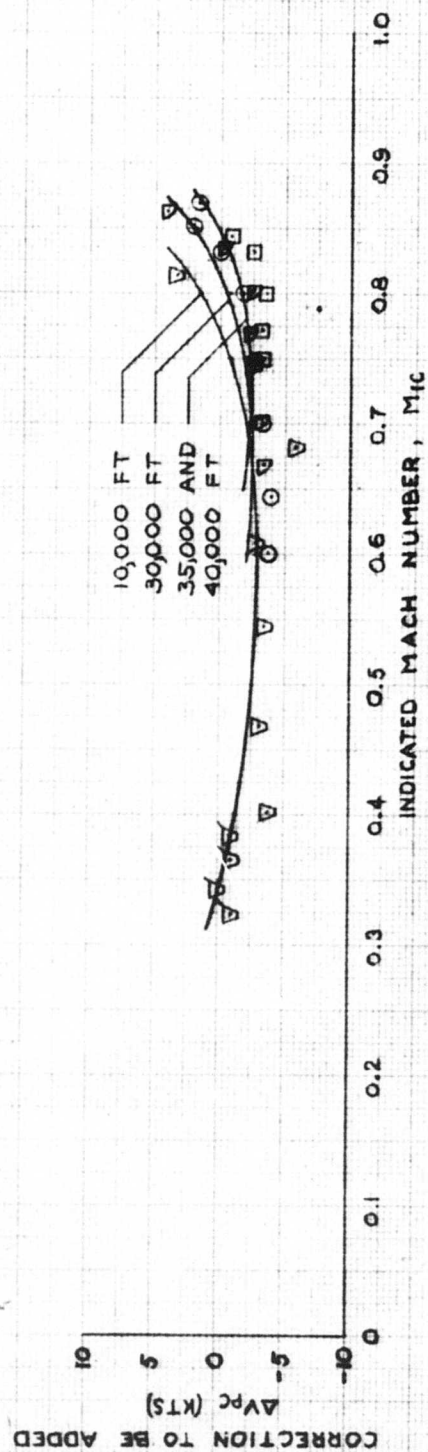


FIGURE 21 STANDBY POSITION ERROR, A-7D 944

A-7D USAF S/N 70-944
REC MODEL 856W-566 COMPENSATING IIOT-STATIC PROBES
LOADING 2: BASIC + 2 300 GAL TANKS

SYMBOL	ALTITUDE/CELT	METHOD	CONFIGURATION
Δ	2,300	TOWER FLY-BY	POWER APPROACH
Δ	2,300	TOWER FLY-BY	CRUISE
▽	10,000	PACE	POWER APPROACH
▽	10,000	PACE	CRUISE
○	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

- NOTES: 1. AAU-19/A ALTIMETER IN RESET
2. DATA OBTAINED BY THE AH METHOD
3. SHADED SYMBOLS ARE DATA OBTAINED WITH LOADING 1

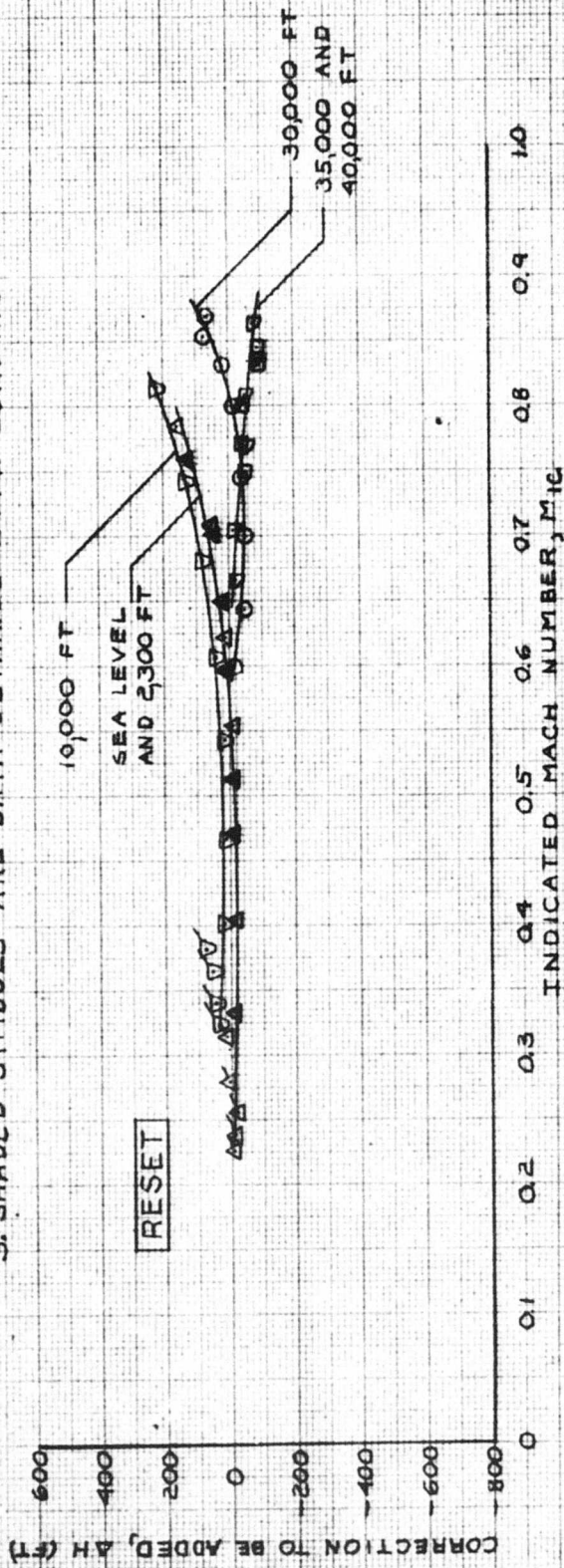


FIGURE 22 RESET POSITION ERROR, A-7D 944

A-7D USAF S/N 71-338
REC MODEL 856 W-5 & 6 COMPENSATING PITOT - STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
Δ	2300	TOWER FLY-BY	CRUISE
Δ	2300	TOWER FLY-BY POWER APPROACH	
▽	10,000	PACE	CRUISE
◇	20,000	PACE	CRUISE
○	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

NOTES: 1. AAU-19/A ALTIMETER IN STANDBY.
2. DATA WERE OBTAINED BY THE ΔH METHOD.

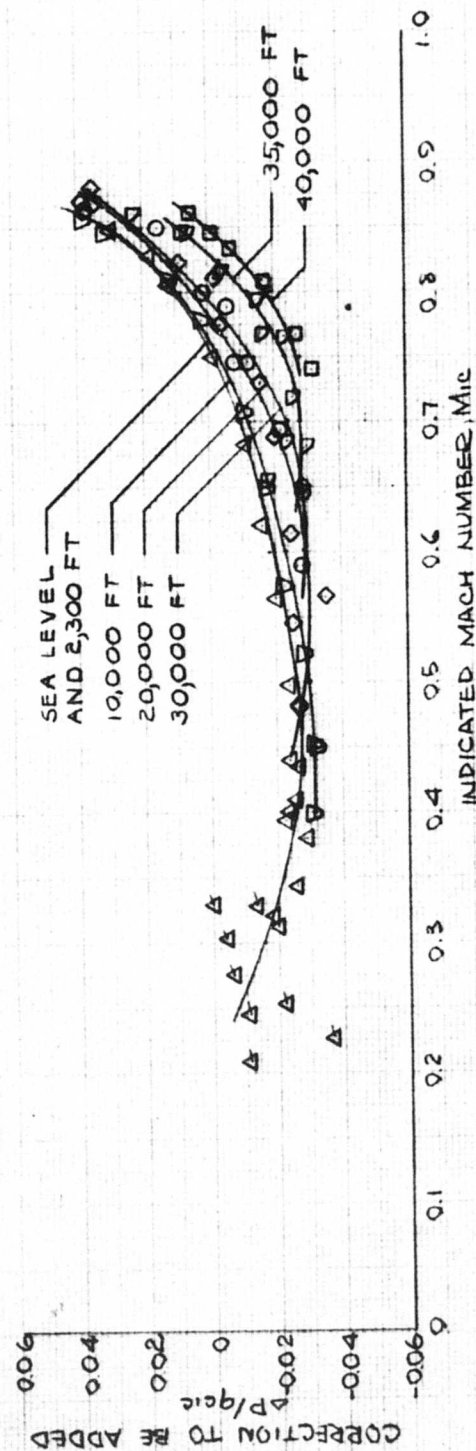


FIGURE 23 STANDBY POSITION ERROR, A-7D 338

A-7D USAF S/N 71-338
REC MODEL 856 W-566 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
A	2,300	TOWER FLY-BY	POWER APPROACH
A	2,300	TOWER FLY-BY	CRUISE
	5,000	PAGE	CRUISE
	6,000	PAGE	CRUISE
V	10,000	PAGE	CRUISE
Q	20,000	PAGE	CRUISE
Q	30,000	PAGE	CRUISE
V	35,000	PAGE	CRUISE
Q	40,000	PAGE	CRUISE

CORRECTION TO BE ADDED, Δh_c (FT)

NOTES: 1. AAU-19/A ALTIMETER IN STANDBY

2. DATA OBTAINED BY THE Δh METHOD

3. FAIRINGS WERE CROSSPLOTED FROM FIGURE 23.

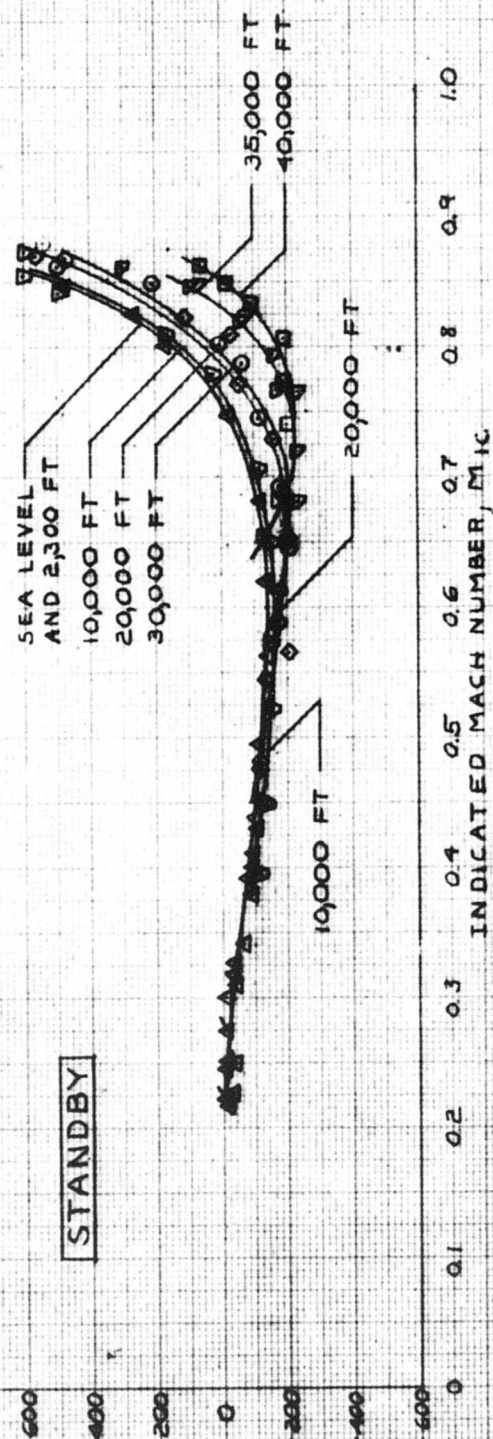


FIGURE 24 STANDBY POSITION ERROR, A-7D 338

A-7D USAF S/N 71-338
REC MODEL 856 W-56 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
Δ	2300	TOWER FLY-BY	CRUISE
△	2300	TOWER FLY-BY	POWER APPROACH
▽	10,000	PACE	CRUISE
◇	20,000	PACE	CRUISE
○	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

- NOTES 1. AAU-19/A ALTIMETER IN STANDBY.
2. DATA WERE OBTAINED BY THE ΔH METHOD.
3. FAIRINGS WERE CROSSPLOTTED FROM FIGURE 23.

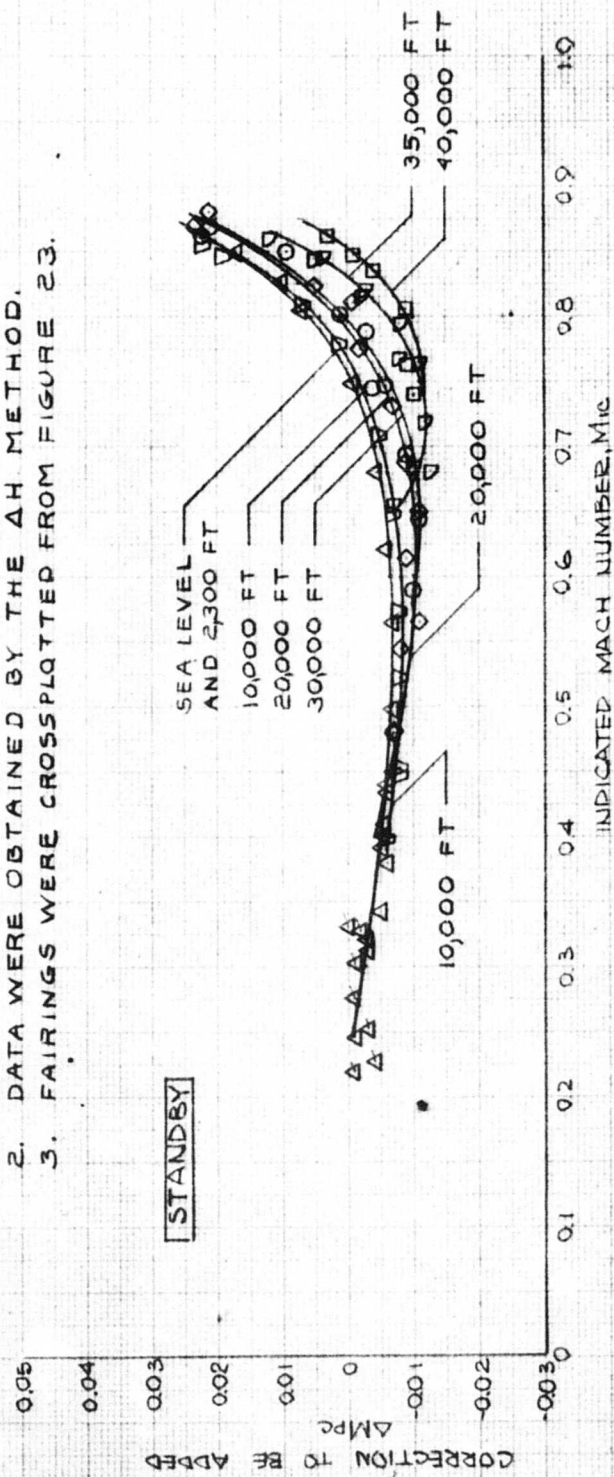


FIGURE 25 STANDBY POSITION ERROR, A-7D 338

A-7D USAF S/N 71-338
 REC MODEL 856 W-56 COMPENSATING PITOT-STATIC PROBES
 LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
Δ	2300	TOWER FLY-BY	CRUISE
▲	2300	TOWER FLY-BY	POWER APPROACH
▽	10000	PACE	CRUISE
◇	20000	PACE	CRUISE
○	30000	PACE	CRUISE
▽	35000	PACE	CRUISE
□	40000	PACE	CRUISE

- NOTES 1. AAU-19/A ALTIMETER IN STANDBY
 2. DATA WERE OBTAINED BY THE ΔH METHOD
 3. FAIRINGS WERE CROSSPLOTTED FROM FIGURE 23

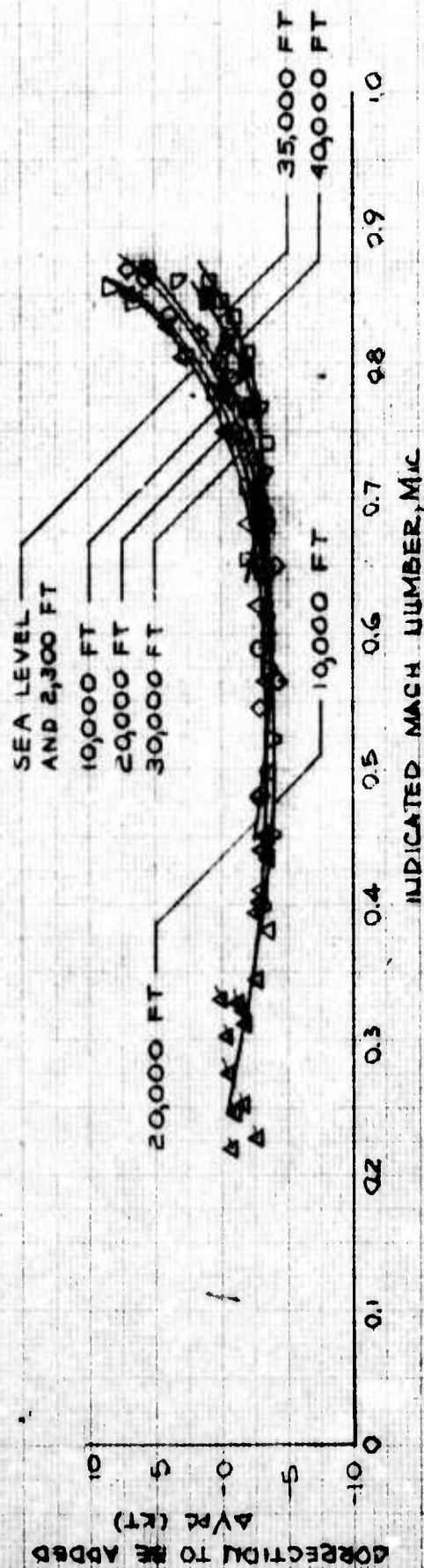


FIGURE 26 STANDBY POSITION ERROR, A-7D 338

A-7D USAF S/N 71-338
REC MODEL 856 W-546 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE(FT)
▽	10,000
◇	20,000
○	30,000
▽	35,000
□	40,000

- NOTES 1. AAU-19/A ALTIMETER IN STANDBY.
2. DATA WERE OBTAINED IN THE CRUISE CONFIGURATION
WITH T-38 PACE BY THE ΔY METHOD.
3. FAIRINGS WERE OBTAINED FROM FIGURE 26.

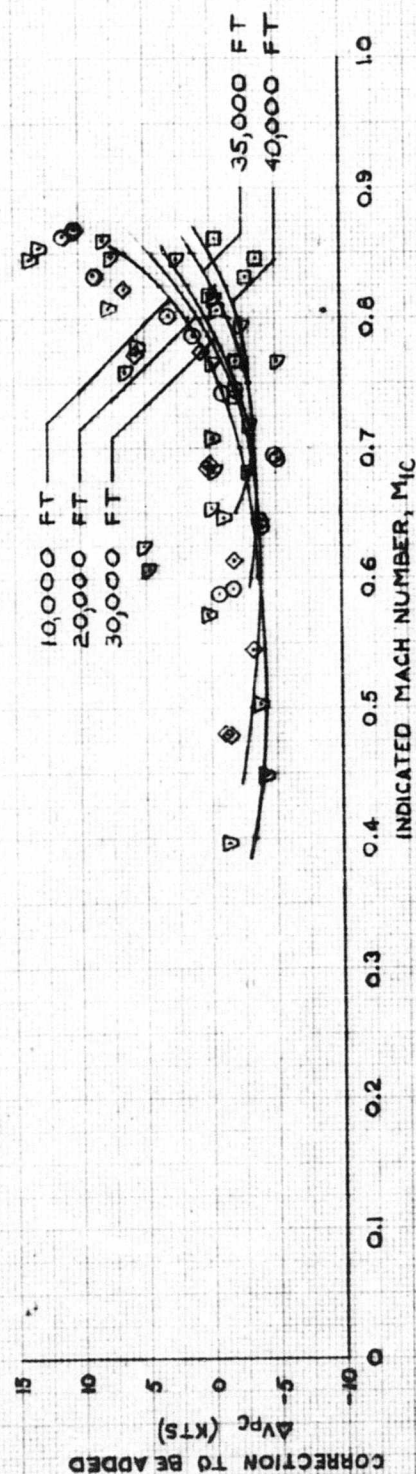


FIGURE 27 STANDBY POSITION ERROR, A-7D 338

A-7D USAF S/N 71-338
REC MODEL 856 W-56 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE	METHOD	CONFIGURATION
A	2,300	TOWER FLY-BY	CRUISE
V	10,000	PACE	CRUISE
Q	20,000	PACE	CRUISE
O	30,000	PACE	CRUISE
N	35,000	PACE	CRUISE
D	40,000	PACE	CRUISE

NOTES: 1. AAU-191A ALTIMETER IN RESET

2. DATA OBTAINED BY THE ΔH METHOD

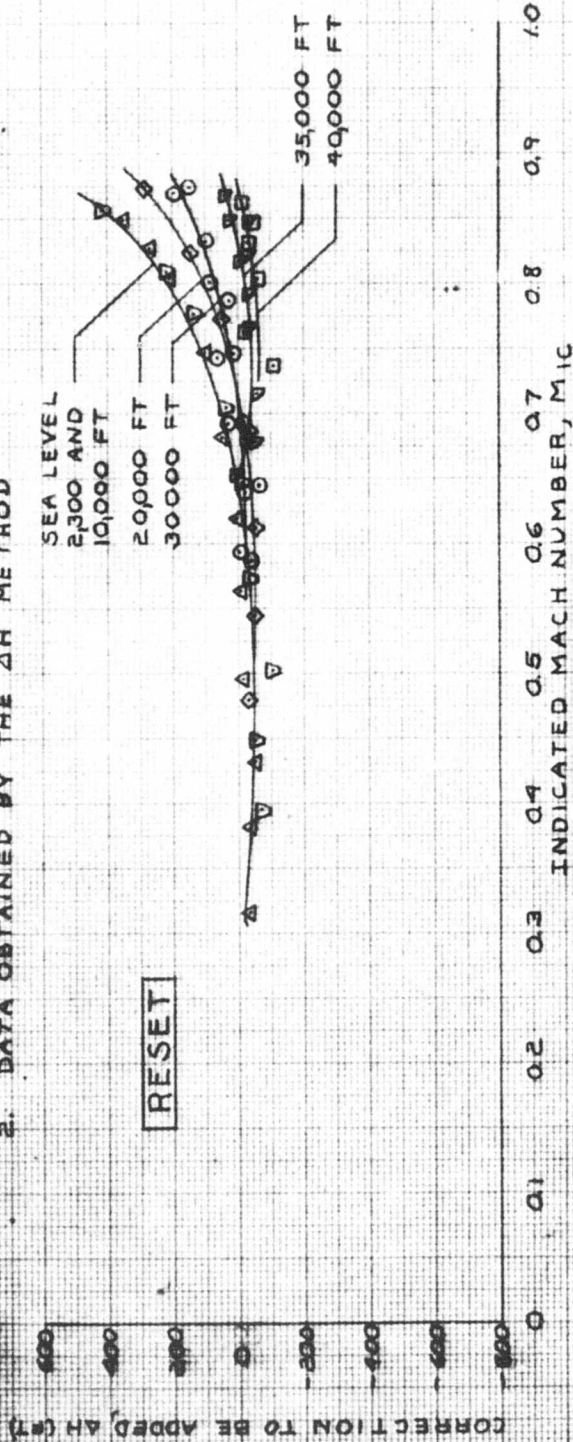


FIGURE 28 RESET POSITION ERROR, A-7D 338

A-7D USAF S/N 71-351
 REC MODEL 856W-516 COMPENSATING PITOT-STATIC PROBES
 LOADING 1

<u>SYMBOL</u>	<u>ALTITUDE (FT)</u>	<u>METHOD</u>	<u>CONFIGURATION</u>
Δ	2,300	TOWER FLY-BY	CRUISE
Δ	2,300	TOWER FLY-BY	POWER APPROACH
O	30,000	PACE	CRUISE
∇	35,000	PACE	CRUISE

NOTES 1. AAU-19/A ALTIMETER IN STANDBY
 2. DATA WERE OBTAINED BY THE AH METHOD

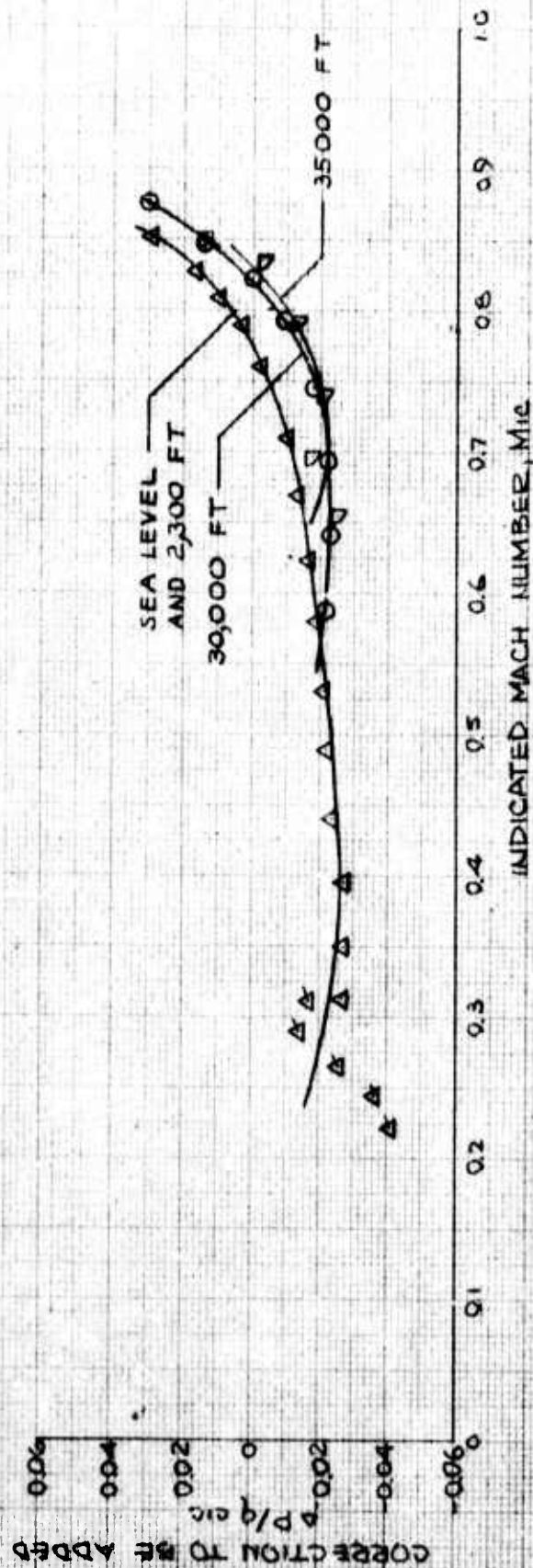


FIGURE 29 STANDBY POSITION ERROR, A-7D 351

A-7D USAF S/N 71-351
REC MODEL 856W-5#6 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SOURCE	ALTITUDE (FT)	METHOD	CONFIGURATION
△	2,300	TOWER FLY BY	POWER APPROACH
△	2,300	TOWER FLY BY	CRUISE
○	30,000	PACE	CRUISE
□	35,000	PACE	CRUISE

NOTES: 1. A-7D 19A ALTIMETER IN STANDBY.
2. DATA OBTAINED BY AH METHOD.
3. FAIRINGS WERE CROSSED PLOTTED FROM FIGURE 29

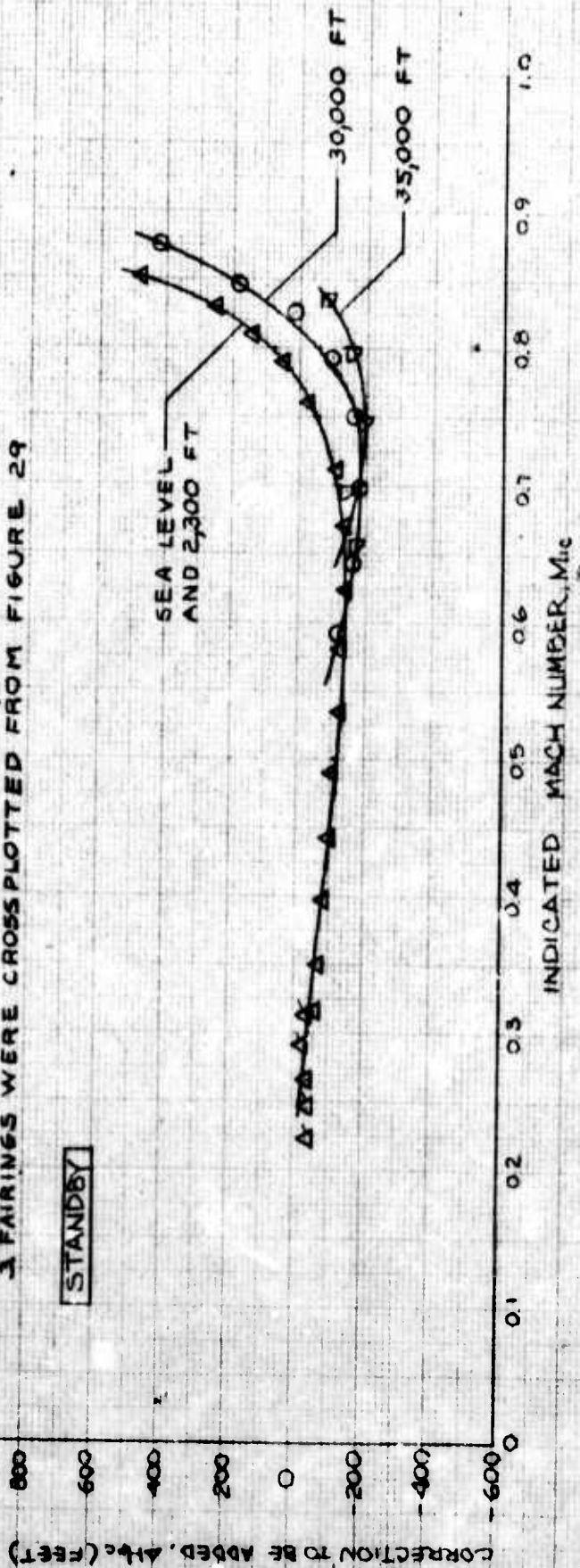


FIGURE 30 STANDBY POSITION ERROR, A-7D 351

A-7D USAF S/N 71-0351

REC MODEL 856W-5+6 COMPENSATING PITOT-STATIC PROBES
LOADING: BASIC (8 PYLONS AND RACKS)

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
△	2,300	TOWER FLY-BY	CRUISE
△	2,300	TOWER FLY-BY	POWER APPROACH
○	30,000	PAGE	CRUISE
▽	35,000	PAGE	CRUISE

- NOTES 1 AAU-19/A ALTIMETER IN STANDBY
2 DATA WERE OBTAINED BY THE ΔH METHOD
3 FAIRINGS WERE CROSSPLOTTED FROM FIGURE 29

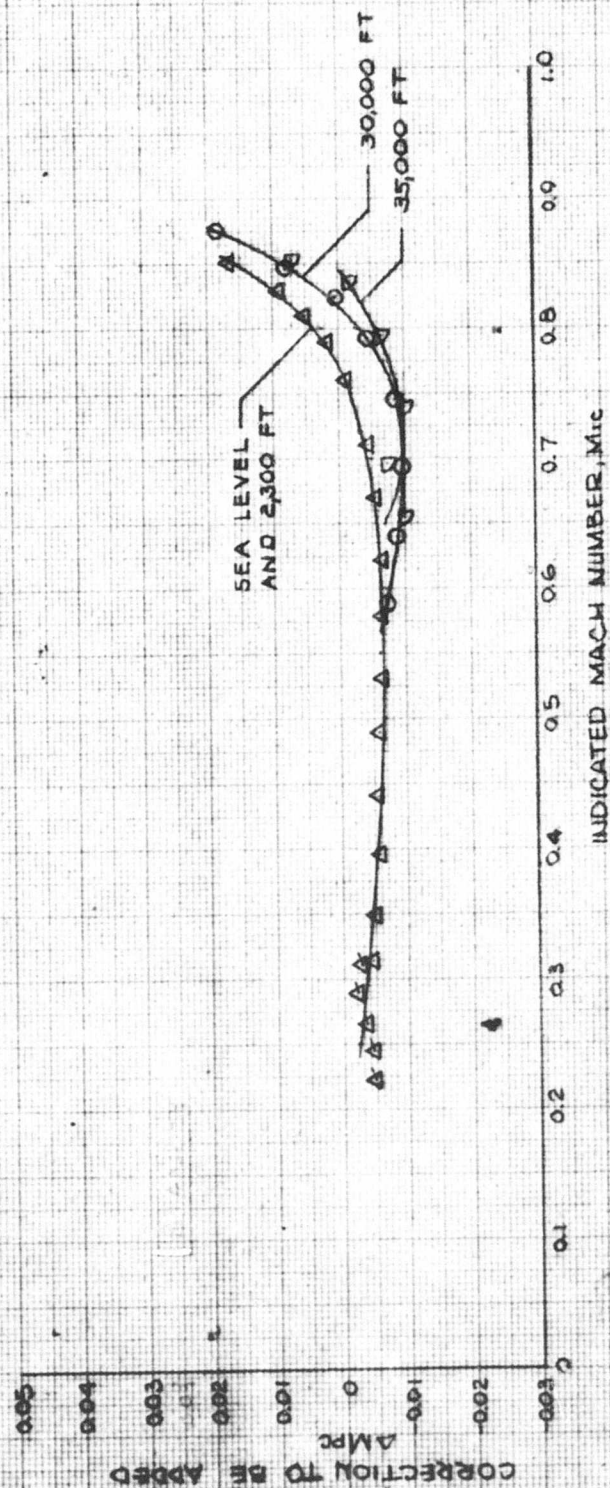


FIGURE 31 STANDBY POSITION ERROR, A-7D 351

A-7D USAF S/N 71-351
 REC MODEL 856W-546 COMPENSATING PILOT-STATIC PROBES
 LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
Δ	2,300	TOWER FLY-BY	CRUISE
Δ	2,300	TOWER FLY-BY	POWER APPROACH
O	30,000	PACE	CRUISE
∇	35,000	PACE	CRUISE

- NOTES 1. AAU-19/A ALTIMETER INSTANDBY
 2. DATA WERE OBTAINED BY THE Δ H METHOD
 3. FAIRINGS WERE CROSSPLOTTED FROM FIGURE 29

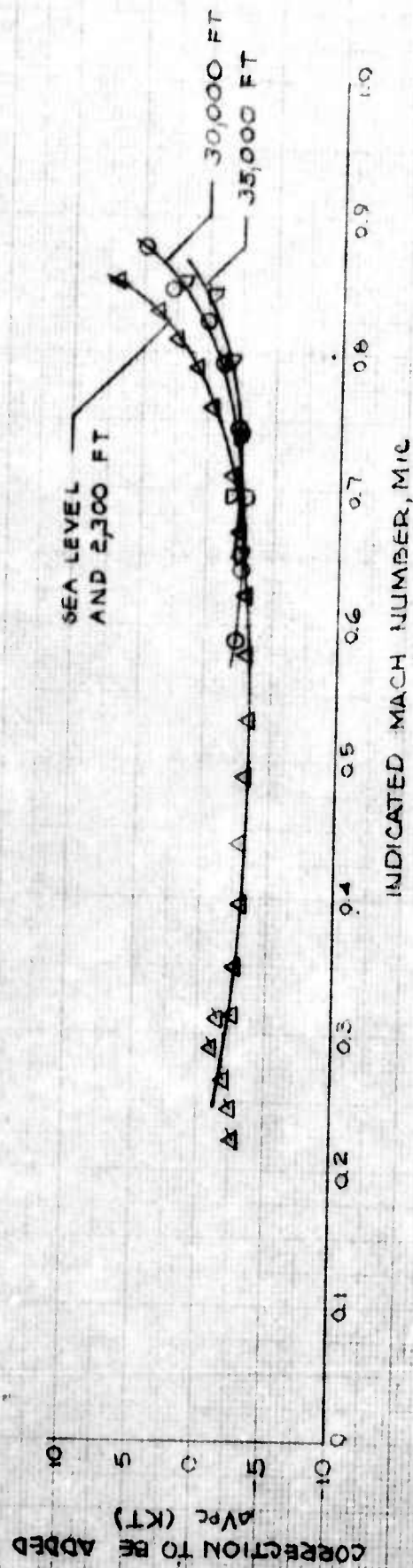


FIGURE 32 STANDBY POSITION ERROR, A-7D 351

A-7D USAF S/N 71-351
 REC MODEL 856W-56 COMPENSATING PITOT-STATIC PROBES
 LOADING 1

SYMBOL	ALTITUDE (FT)
○	30,000
▽	35,000

- NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
 2. DATA WERE OBTAINED IN THE CRUISE CONFIGURATION
 WITH T-38 PACE BY THE ΔV METHOD
 3. FAIRINGS WERE OBTAINED FROM FIGURE 32.

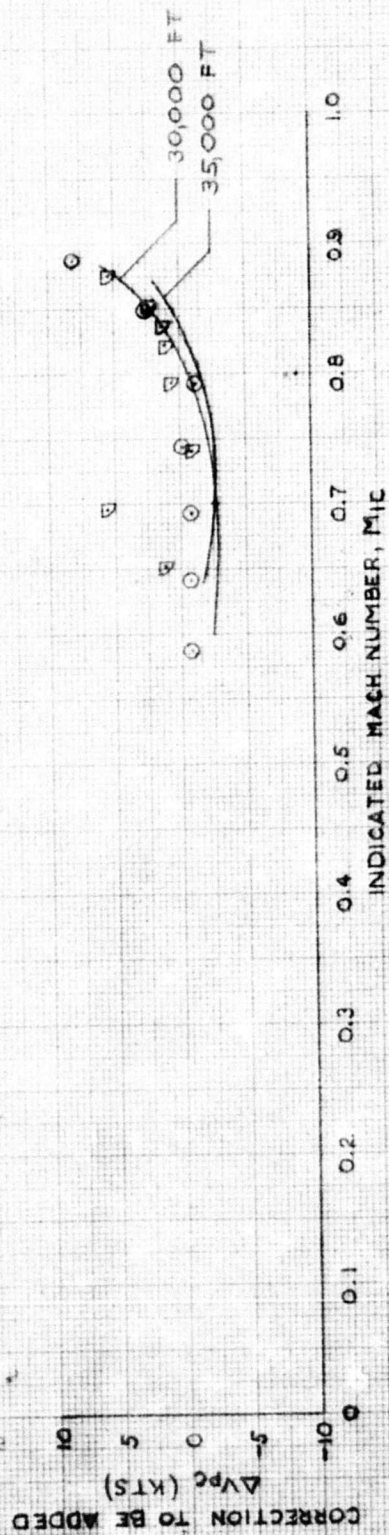


FIGURE 33. STANDBY POSITION ERROR, A-7D 351

A-7D USAF S/N 71-351
REC MODEL 856W-566 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE(FT)	METHOD	CONFIGURATION
A	2,300	TOWER FLY-BY	POWER APPROACH
A	2,300	TOWER FLY-BY	CRUISE
O	30,000	PAGE	CRUISE
S	35,000	PAGE	CRUISE

NOTES: 1. AAU-19/A ALTIMETER IN RESET
2. DATA OBTAINED BY THE ΔH METHOD

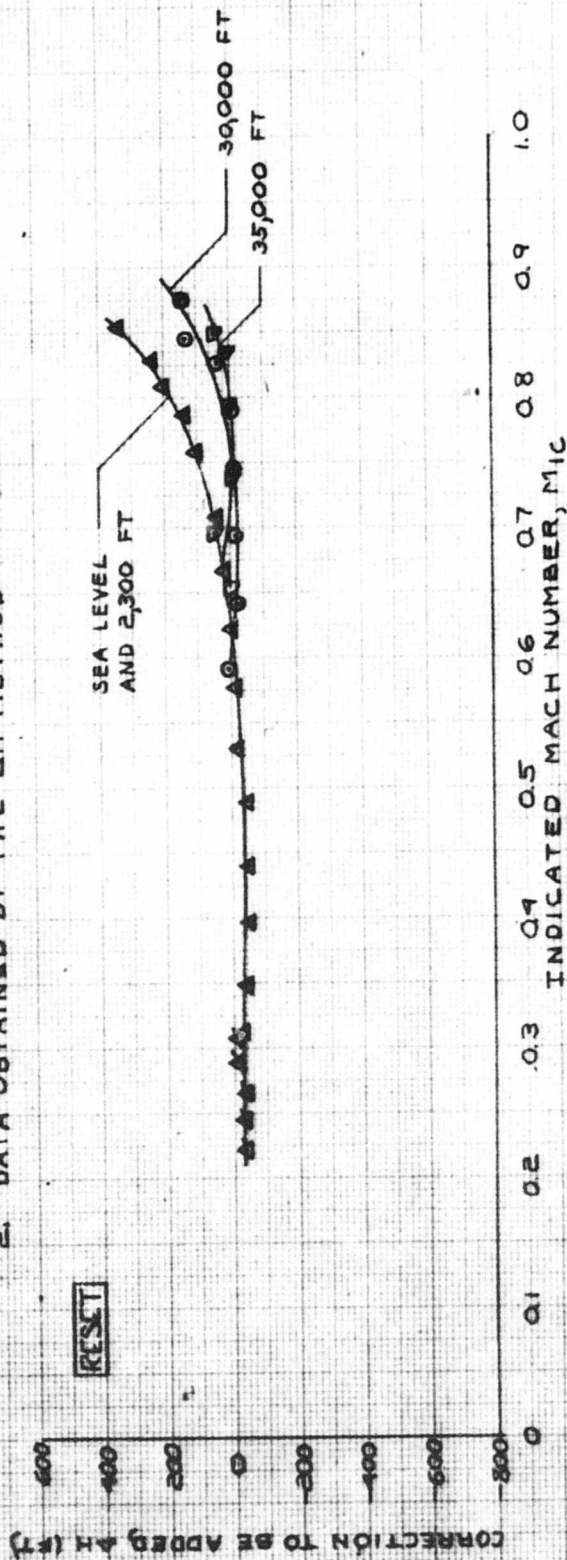


FIGURE 34 RESET POSITION ERROR, A-7D 351

AIMS MODIFIED A-7D AIRCRAFT REC MODEL 856 W-566 COMPENSATING PITOT-STATIC PROBES

NOTE: THE FAIRINGS WERE OBTAINED FROM THE STANDBY DATA
OBTAINED ON A-7D 338, 331, 944, AND 973.

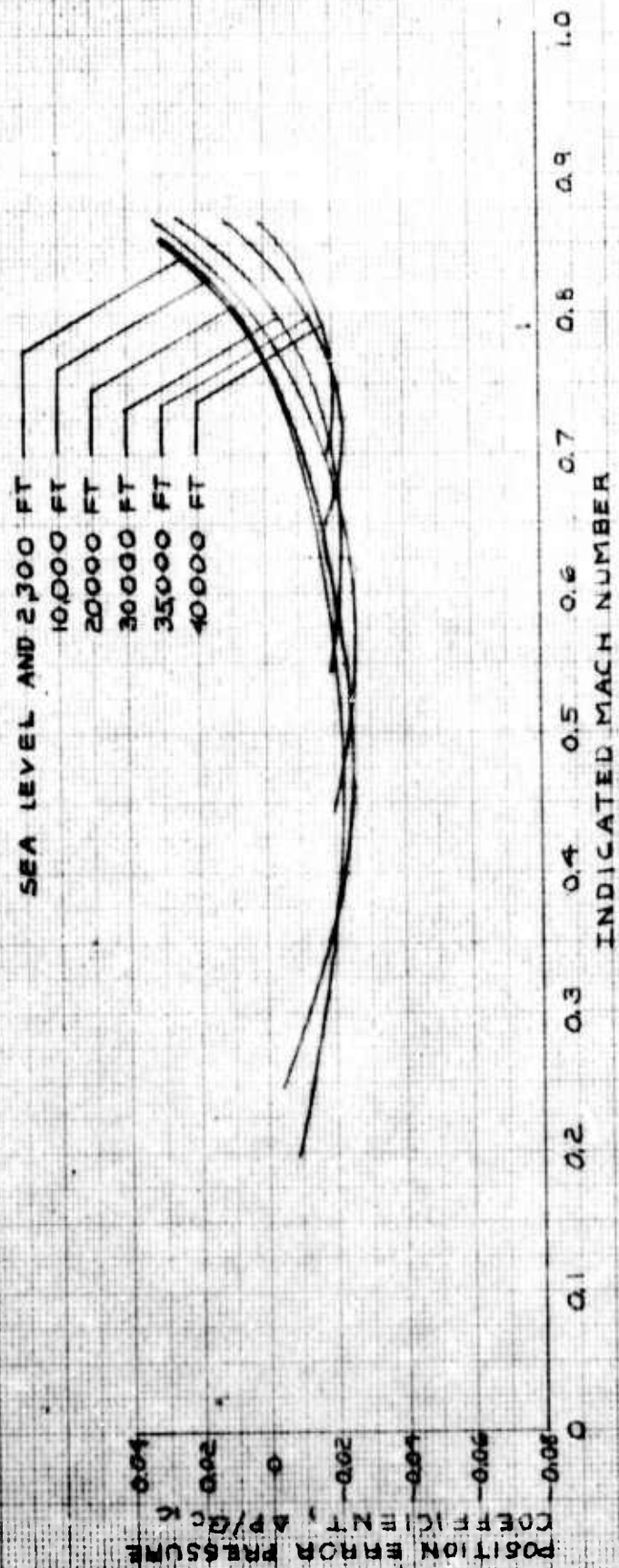
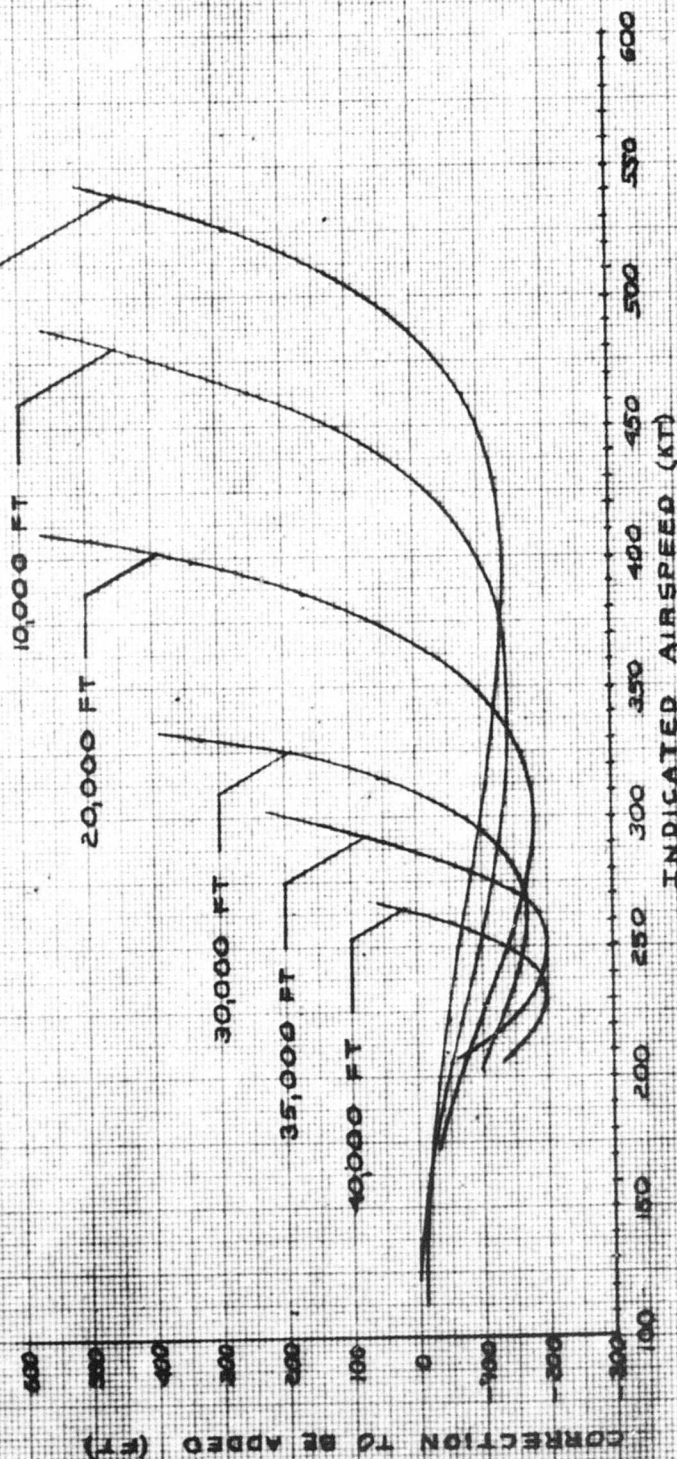


FIGURE 35 REPRESENTATIVE $AP/Q_c K$ CORRECTION

POSITION ERROR CORRECTION

ALTITUDE CORRECTION
ALL CONDITIONS
AAU-19/A PNEUMATIC (STDB) MODE
SEA LEVEL AND 2,300 FT



PRESSURE ALTITUDE (CALIBRATED ALTITUDE) = INDICATED ALTITUDE + CORRECTION

FIGURE A1-5 (SHEET 1)

FIGURE 36 RECOMMENDED FLIGHT MANUAL A10X CORRECTION

POSITION ERROR CORRECTION

ALTITUDE CORRECTION

CRUISE CONDITION

AAU-19/A SERVO (RESET) MODE

PRESSURE ALTITUDE (CALIBRATED ALTITUDE) = INDICATED ALTITUDE + CORRECTION

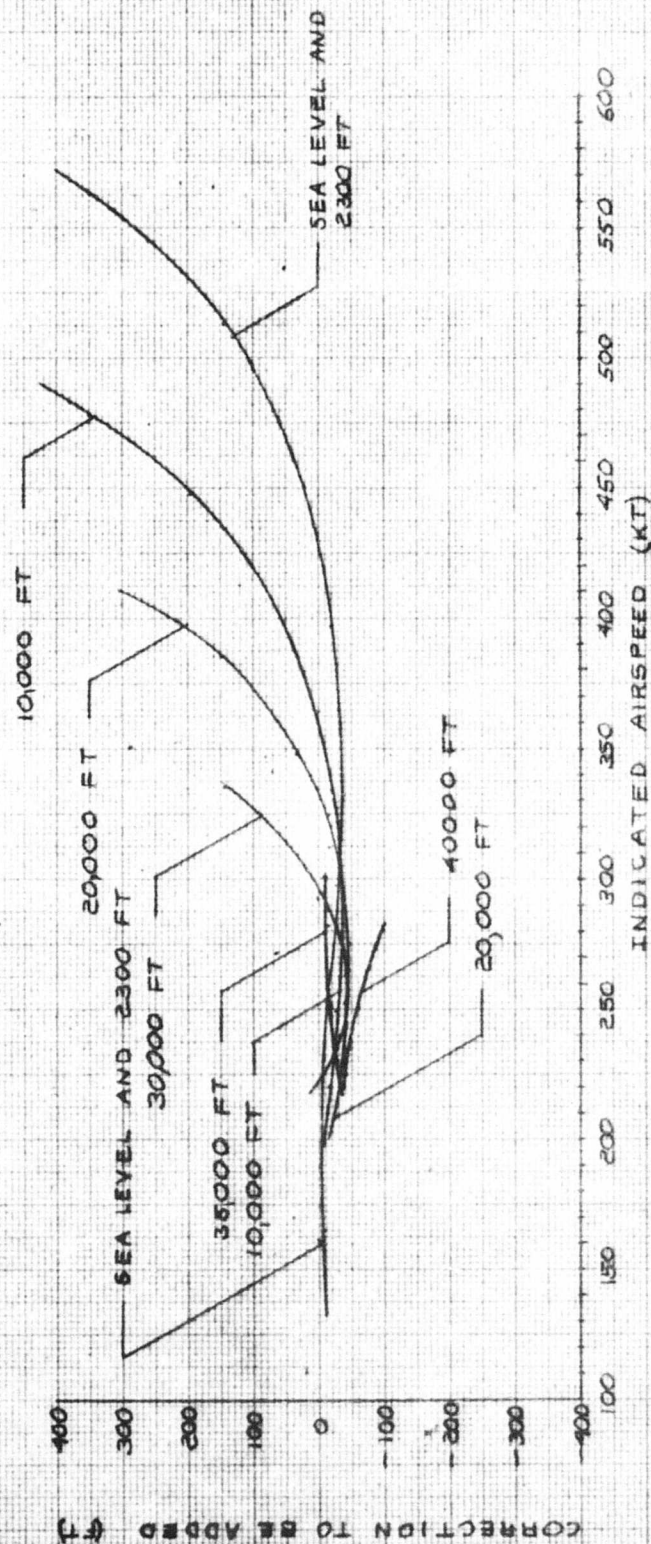


FIGURE A1-5 (SHEET 2)

POSITION ERROR CORRECTION

AIRSPED CORRECTION
ALL CONDITIONS

CALIBRATED AIRSPED = INDICATED AIRSPED + CORRECTION

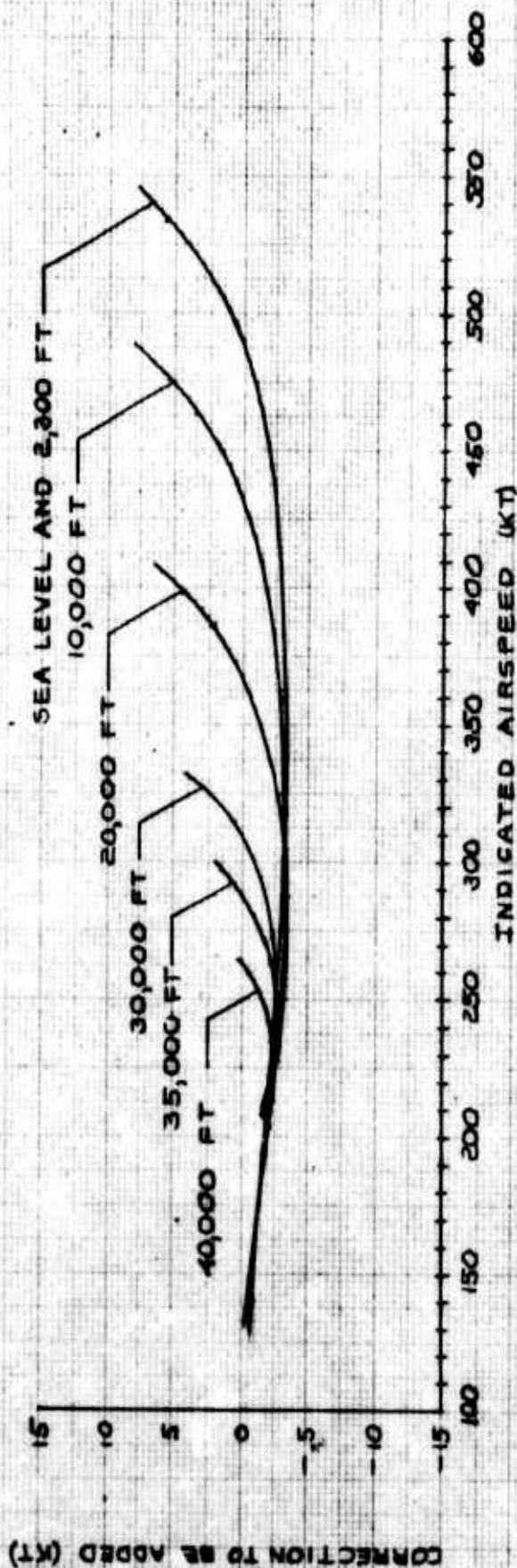


FIGURE A1-5(SHEET 4)

FIGURE 38 RECOMMENDED FLIGHT MANUAL AYPC CORRECTION

POSITION ERROR CORRECTION

MACH NUMBER CORRECTION

TRUE MACH NUMBER = INDICATED MACH NUMBER + CORRECTION

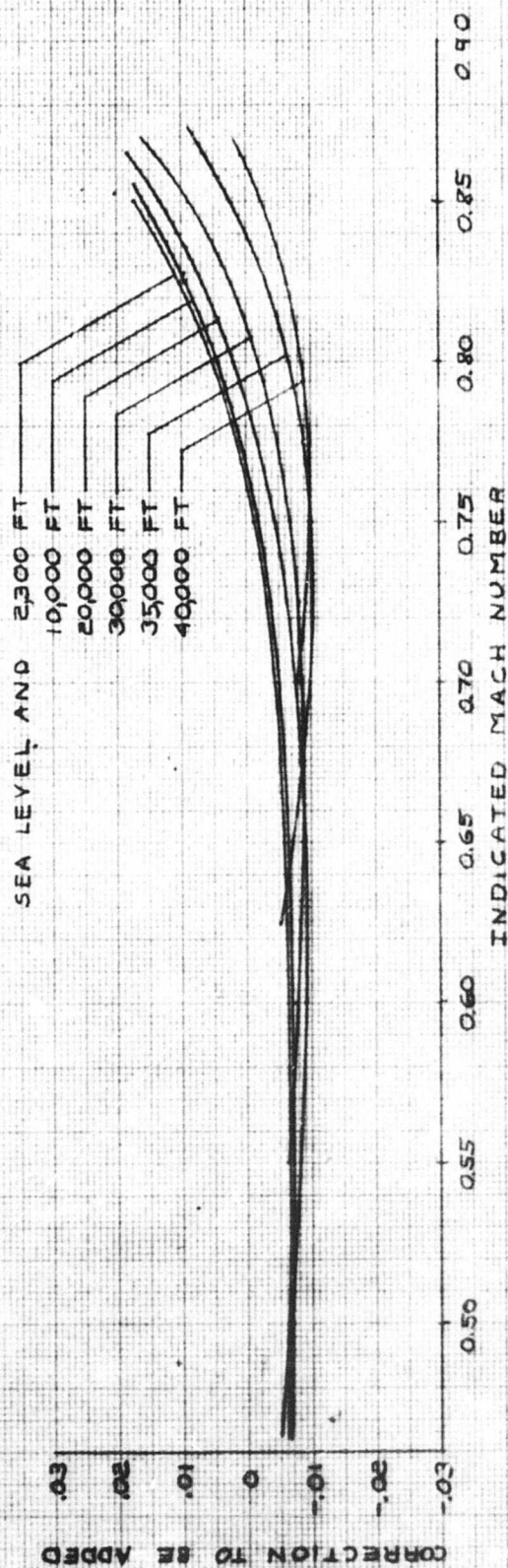


FIGURE A1-5 (SHEET 5)

AIMS MODIFIED A-7D AIRCRAFT REC MODEL 856W-546 COMPENSATING PITOT-STATIC PROBES

- NOTES: 1. THE AIMS-MODIFICATION DID NOT MEET THE AIMS LEVEL 3 CRITERION IN THE RESET MODE IN THE CROSS-HATCHED AREA OF THE FLIGHT ENVELOPE.
2. THE FLIGHT REGIMES WERE BASED ON THE RESET POSITION ERROR FAIRINGS SHOWN IN FIGURE 37.

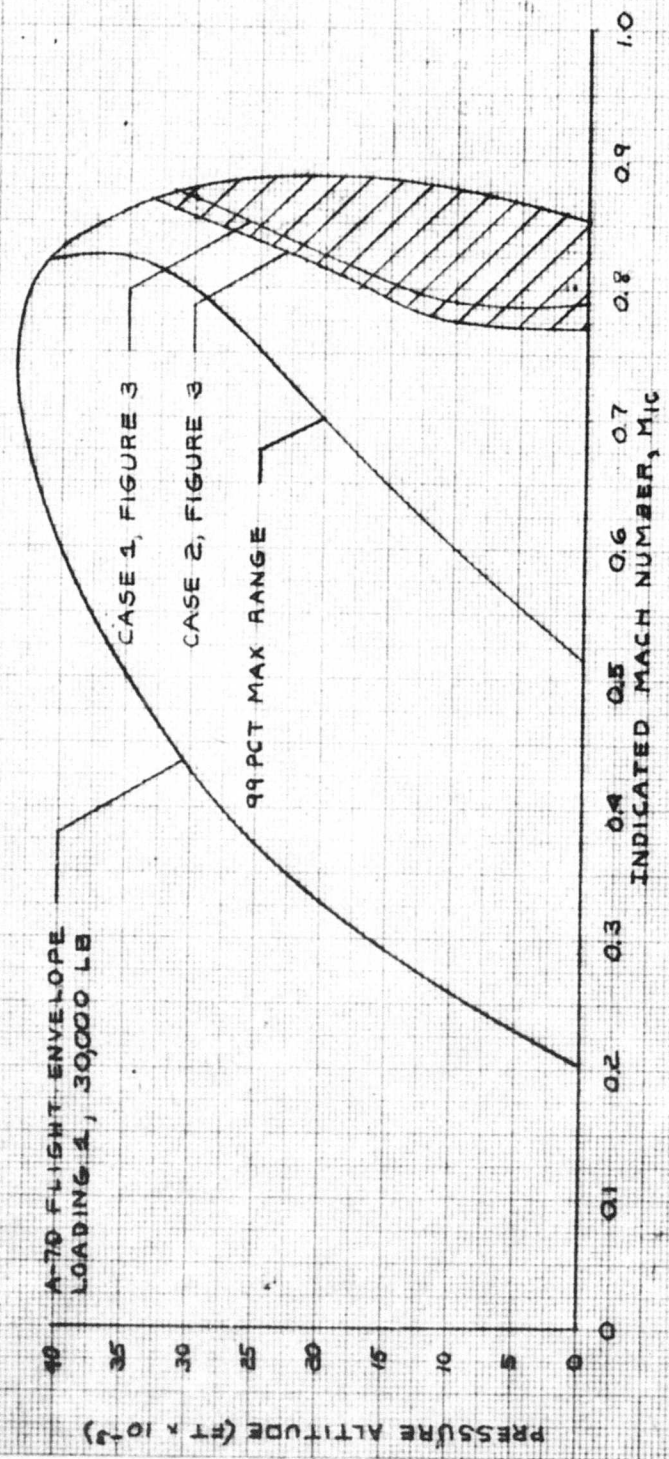


FIGURE 40 LEVELS 3 AND 4 FLIGHT REGIMES, A-7D AIRCRAFT

AIMS MODIFIED A-7D AIRCRAFT REC MODEL 856 W-546 COMPENSATING PITOT-STATIC PROBES LOADING 1

SOURCE	ALTITUDE (FT)	METHOD	CONFIGURATION
A	2,300	TOWER FLY BY	POWER APPROACH
V	10,000	PACE	POWER APPROACH

- NOTES 1. AAU-19/A ALTIMETER IN RESET
2. DATA WAS OBTAINED BY THE AH METHOD
3. IT WAS ASSUMED THAT AN EQUIVALENT POSITION ERROR
CHANGE OCCURRED IN STANDBY
4. FLIGHT MANUAL POSITION ERROR FOR THE POWER APPROACH
CONFIGURATION IN THE STANDBY MODE WAS NOT AVAILABLE

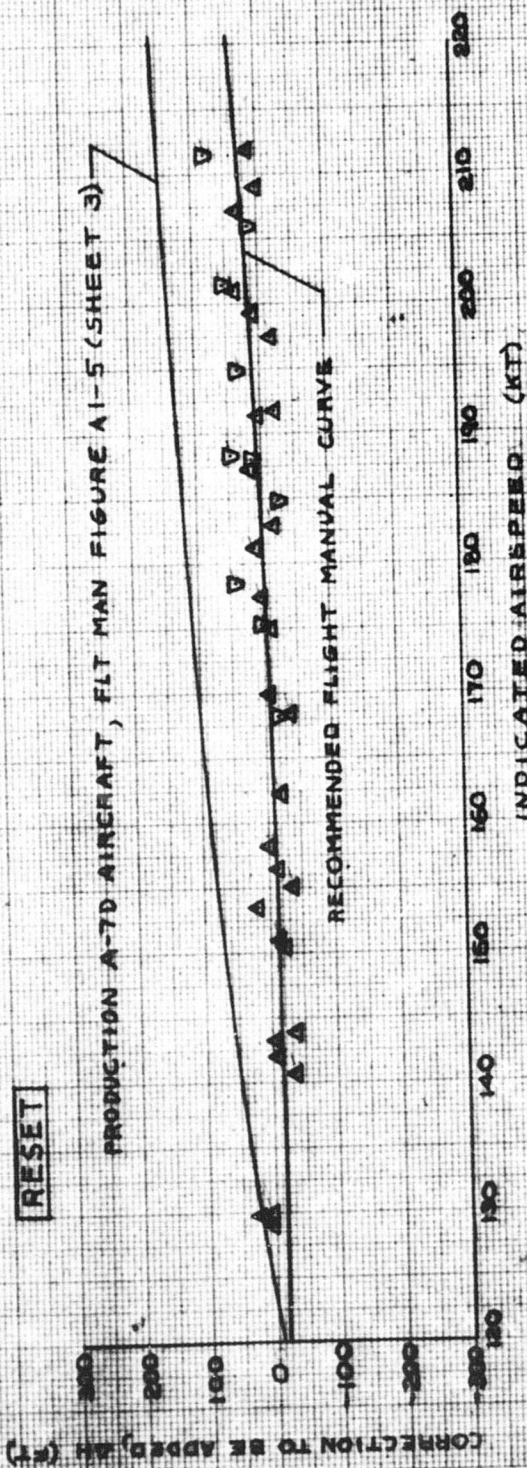


FIGURE 41 POWER APPROACH AH CORRECTION

POSITION ERROR CORRECTION

ALTITUDE CORRECTION
LANDING CONDITION
AAU-19/A SERVO(RESET) MODE

PRESSURE ALTITUDE (CALIBRATED ALTITUDE) =
INDICATED ALTITUDE + CORRECTION

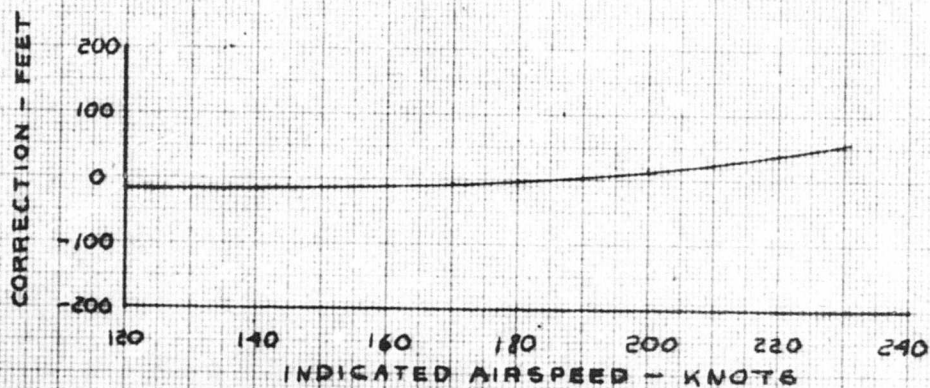


FIGURE A1-5 (SHEET 3)

A-7D USAF S/N 70-0973
REC MODEL 856 W-566 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION	RUDDER DEFLECTION
D	10,000	PAGE	CRUISE	1/2 BALL DIAMETER
D	10,000	PAGE	CRUISE	1/2 BALL DIAMETER
A	10,000	PAGE	CRUISE	1/2 RUDDER
V	10,000	PAGE	CRUISE	FULL RUDDER

NOTES: 1. DATA OBTAINED BY THE AH METHOD AND APPLIES TO THE
 STANDBY AND RESET MODES
 2. CORRECTION TO BE ADDED IS IN ADDITION TO THE NORMAL
 STANDBY OR RESET CORRECTION.

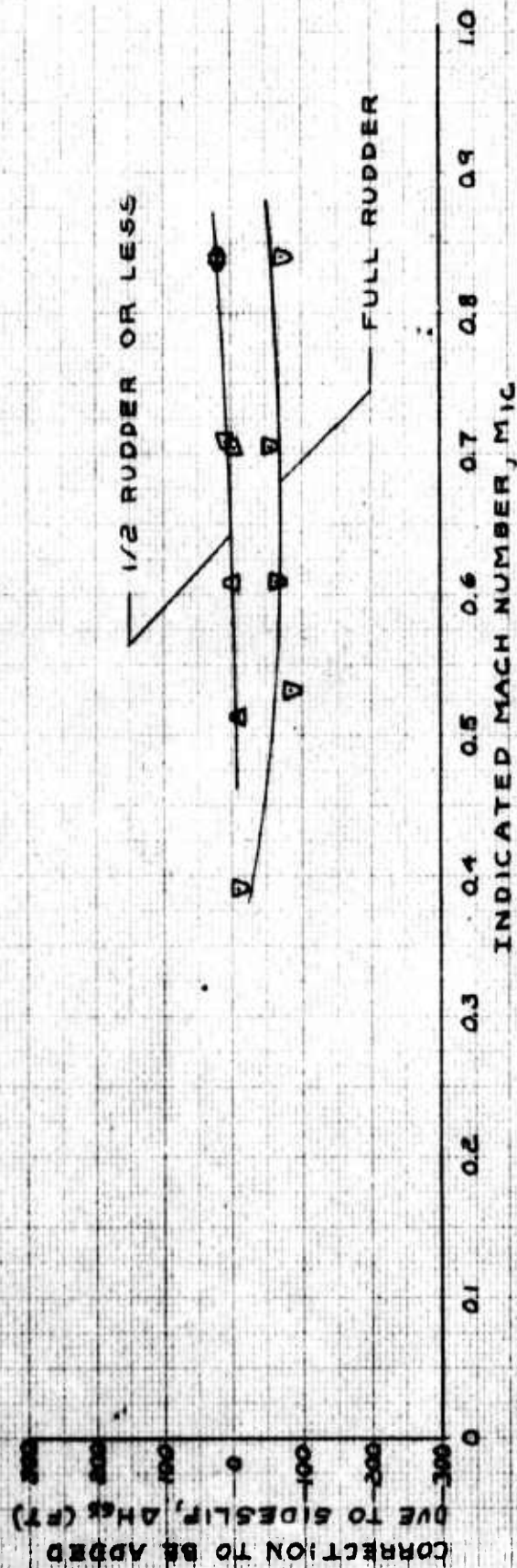


FIGURE 43 POSITION ERROR DUE TO SIDESLIP

A-7D USAF S/N 71-338
 REC MODEL 856W-546 COMPENSATING PITOT-STATIC PROBES
 LOADING 1

NOTES 1. DATA WERE OBTAINED WITH ASKANIA PHOTOHEODOLITE CAMERAS
 2. SYMBOLS REPRESENT TWO TAKEOFFS
 3. DATA WERE OBTAINED WITH A 5 DEG NOSE-UP PITCH ATTITUDE,

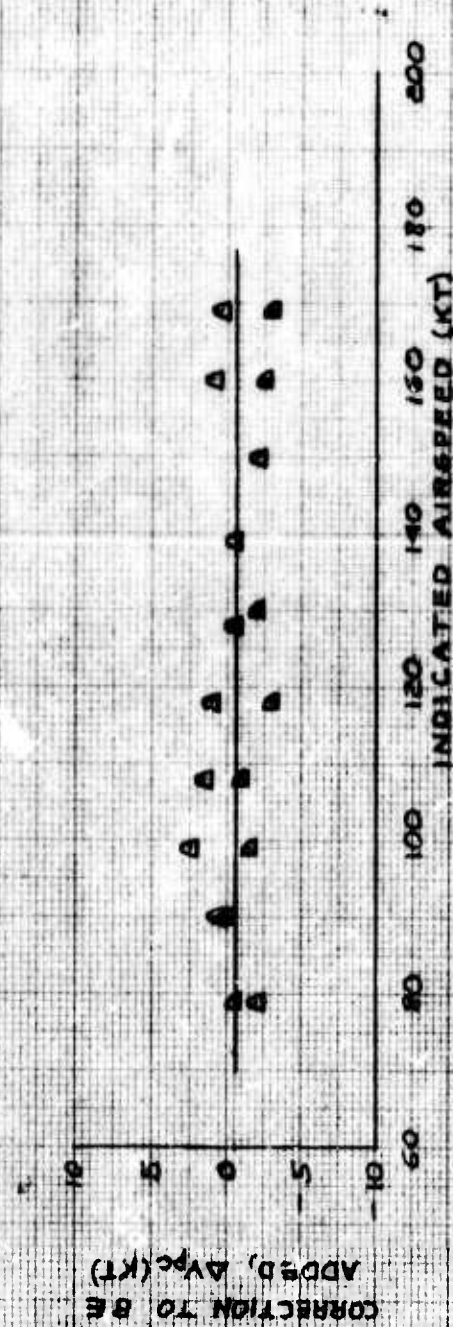


FIGURE 14 14 - GROUND-EFFECT POSITION ERROR, GROUND RUN ACCELERATIONS

A-7D USAF S/N 71-338
 REC MODEL 856 W-546 COMPENSATING PITOT-STATIC PROBES
 LOADING 1

- NOTES 1. DATA WERE OBTAINED WITH ASKANIA PHOTOHEADOLITE
 CAMERAS
 2. SYMBOLS REPRESENT TWO TAKEOFFS
 3. DATA WERE OBTAINED WITH A 5 DEG NOSE-UP PITCH
 ATTITUDE

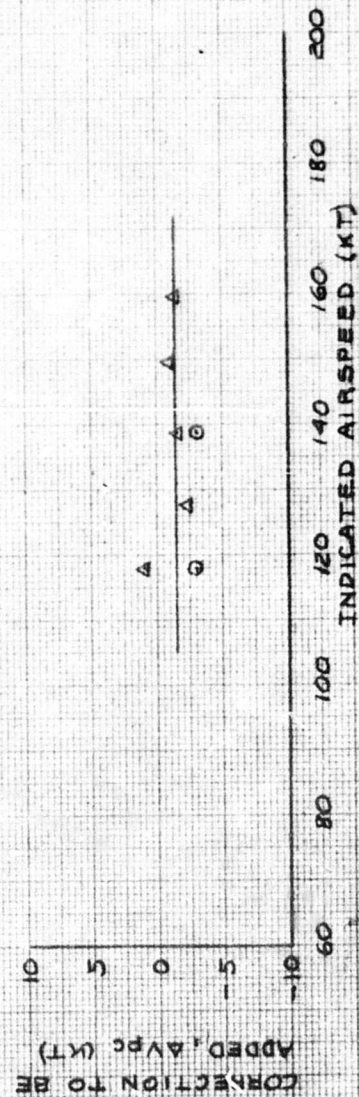


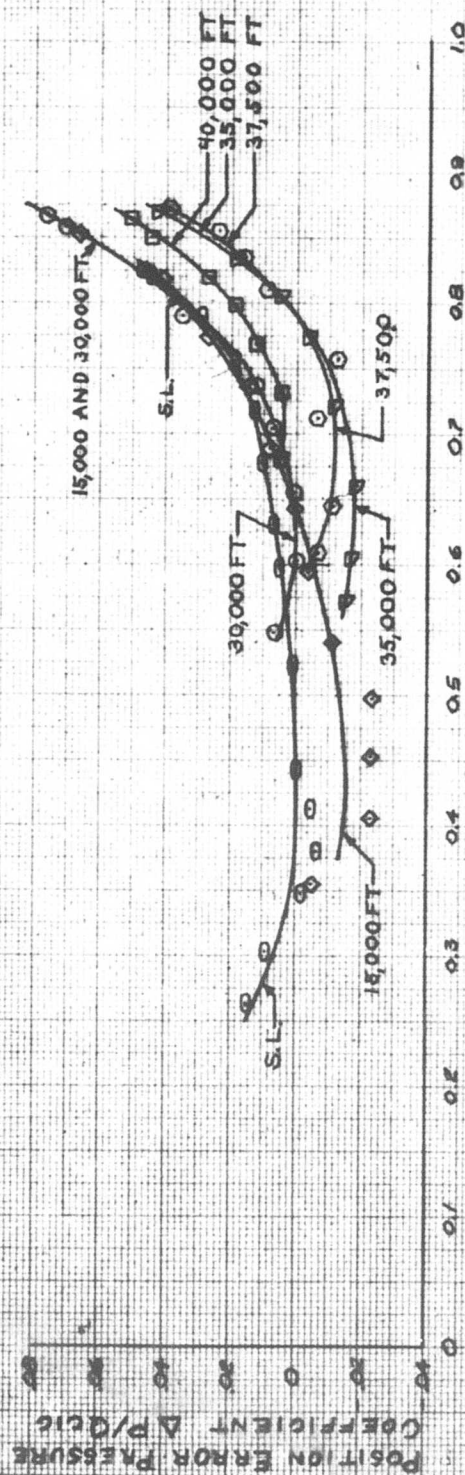
FIGURE 45 IN-GROUND-EFFECT POSITION ERROR, TAKEOFF ATTITUDE

A-7E USN BN 156752
 REC-MODEL 856 W-1(LT), REV J AND W-4, REVA PITOT-STATIC PROBES
 LOADING 1
 CRUISE CONFIGURATION

SYMBOL	ALTITUDE (FT)	METHOD
○	SEA LEVEL	TOYER FLY-BY
◇	15,000	PAGE
○	30,000	PAGE
▽	35,000	PAGE
○	37,500	PAGE
□	40,000	PAGE

NOTES: 1. AAU-19/A IN STANDBY

2. DATA REDUCED BY THE ΔH METHOD



INDICATED MACH NUMBER, M_{∞}
 FIGURE 46. STANDBY POSITION ERROR, A-7E 752

A-7E USN B/N 156752
 REG MODEL 856 W-1 (LT), REV J AND W-4, REVA PITOT-STATIC PROBES
 LOADING 1
 CRUISE CONFIGURATION

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
□	SEA LEVEL	TOVER FLY-BY	POWER APPROACH
○	SEA LEVEL	TOVER FLY-BY	CRUISE
◇	15,000	PACE	CRUISE
○	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
○	37,500	PACE	CRUISE
□	40,000	PACE	CRUISE

NOTES: 1. AAV-191A IN STANDBY

2. DATA REDUCED BY THE ΔH METHOD

3. FAIRINGS WERE GROSS PLOTTED FROM FIGURE 46

CORRECTION TO BE ADDED, Δh_p (FT)

STANDBY

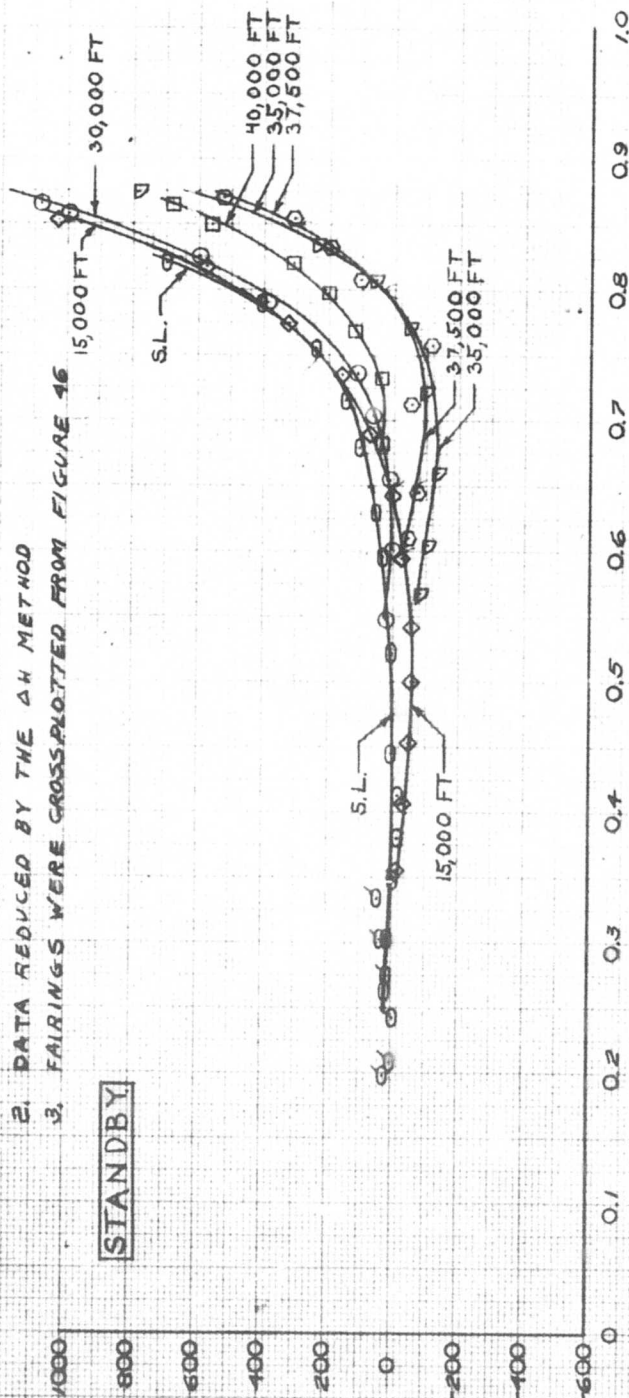


FIGURE 47 STANDBY POSITION ERROR, A-7E 752
 INDICATED MACH NUMBER, M_c

A-7E USN B/N 156 752
 REC MODEL 856 W-1, REV J AND W-4, REV A PITOT-STATIC PROBES
 LOADING 1

NOTE FAIRINGS WERE OBTAINED BY APPLYING THE ADC CORRECTION
 (TABLE 3) TO THE FAIRINGS OF FIGURE 47.

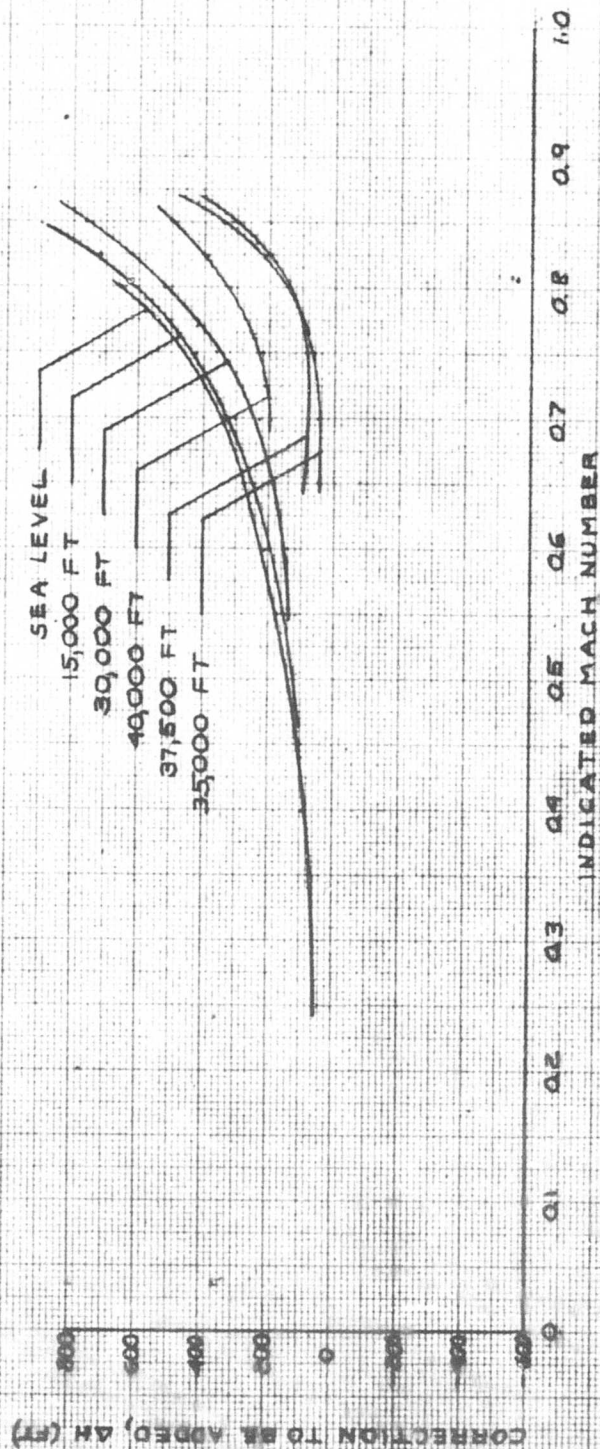


FIGURE 49 A-7E PREDICTED RESET CORRECTION, W-5 AND 6 ADC CAMS

REC MODEL 856W-1, REV J AND W-4, REV A PITOT-STATIC PROBES AIMS MODIFIED A-7E AIRCRAFT

- NOTES: 1 THE ENVELOPE AND THE 99 PCT MAX RANGE LINE WERE OBTAINED FROM THE A-7D FLIGHT MANUAL FOR LOADING 1 WITH A GROSS WEIGHT OF 30,000 LB.
- 2 THE AIMS MODIFICATION DID NOT MEET THE AIMS LEVEL 3 CRITERION IN THE RESET MODE ($|AH| \leq 250$ FEET) IN THE CROSS-HATCHED AREA OF THE FLIGHT ENVELOPE.
- 3 THE PREDICTION WAS BASED ON THE PREDICTED RESET POSITION ERROR SHOWN IN FIGURE 48.

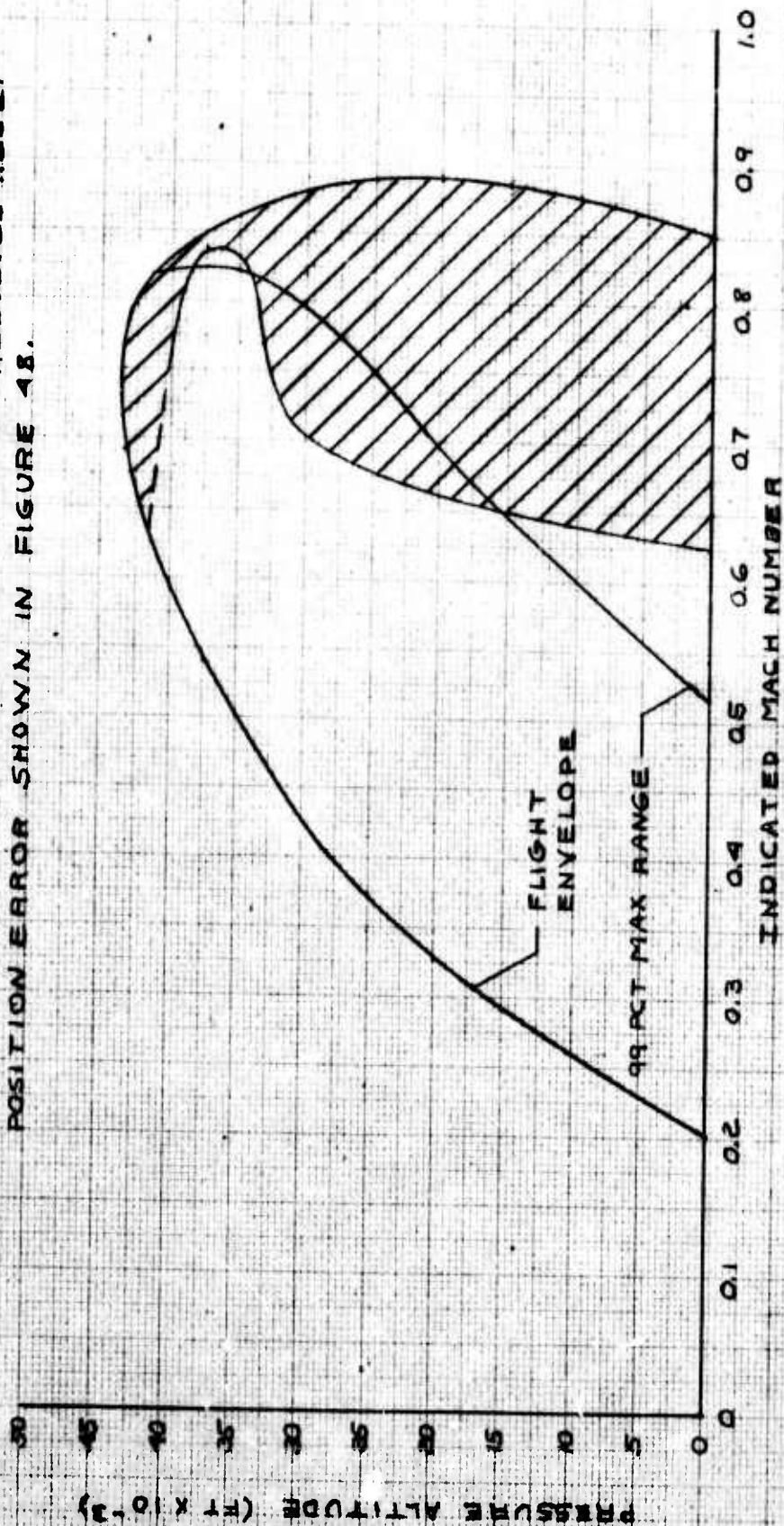


FIGURE 49 A-7E LEVELS 3 AND 4 FLIGHT REGIME, W-5 AND 6 ADC CAMS

A-7E USN B/N 156752
 REC MODEL 856 W-1, REV J AND W-4, REV A PITOT-STATIC PROBES
 LOADING 1

NOTE FAIRINGS WERE OBTAINED BY APPLYING THE ADC CORRECTION
 (TABLE 4) TO THE FAIRINGS OF FIGURE 47.

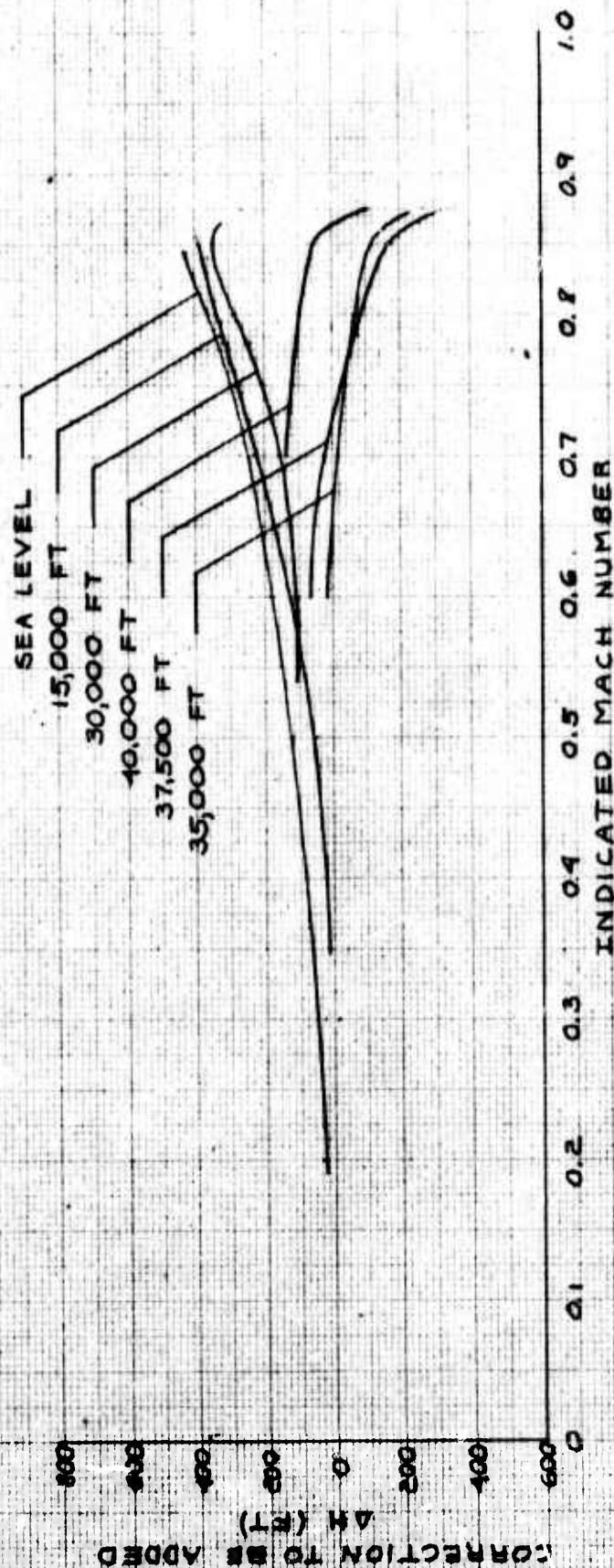


FIGURE 50 A-7E PREDICTED RESET CORRECTION, 30,000 FOOT REV J ADC CAMS

AIMS MODIFIED A-7E AIRCRAFT REC MODEL 856 W-1, REV J AND W-4, REV A PITOT-STATIC PROBES

- NOTES:
1. THE FLIGHT ENVELOPE AND THE 99 PCT MAX RANGE LINE WERE OBTAINED FROM THE A-7D FLIGHT MANUAL FOR LOADING 1 WITH A GROSS WEIGHT OF 30,000 LB.
 2. THE AIMS MODIFICATION, IN THE CROSS HATCHED AREA, DID NOT MEET THE AIMS LEVEL 3 CRITERION IN THE RESET MODE, JAN 4 250 FEET.
 3. THE PREDICTION WAS BASED ON THE PREDICTED RESET POSITION ERROR SHOWN IN FIGURE 50.

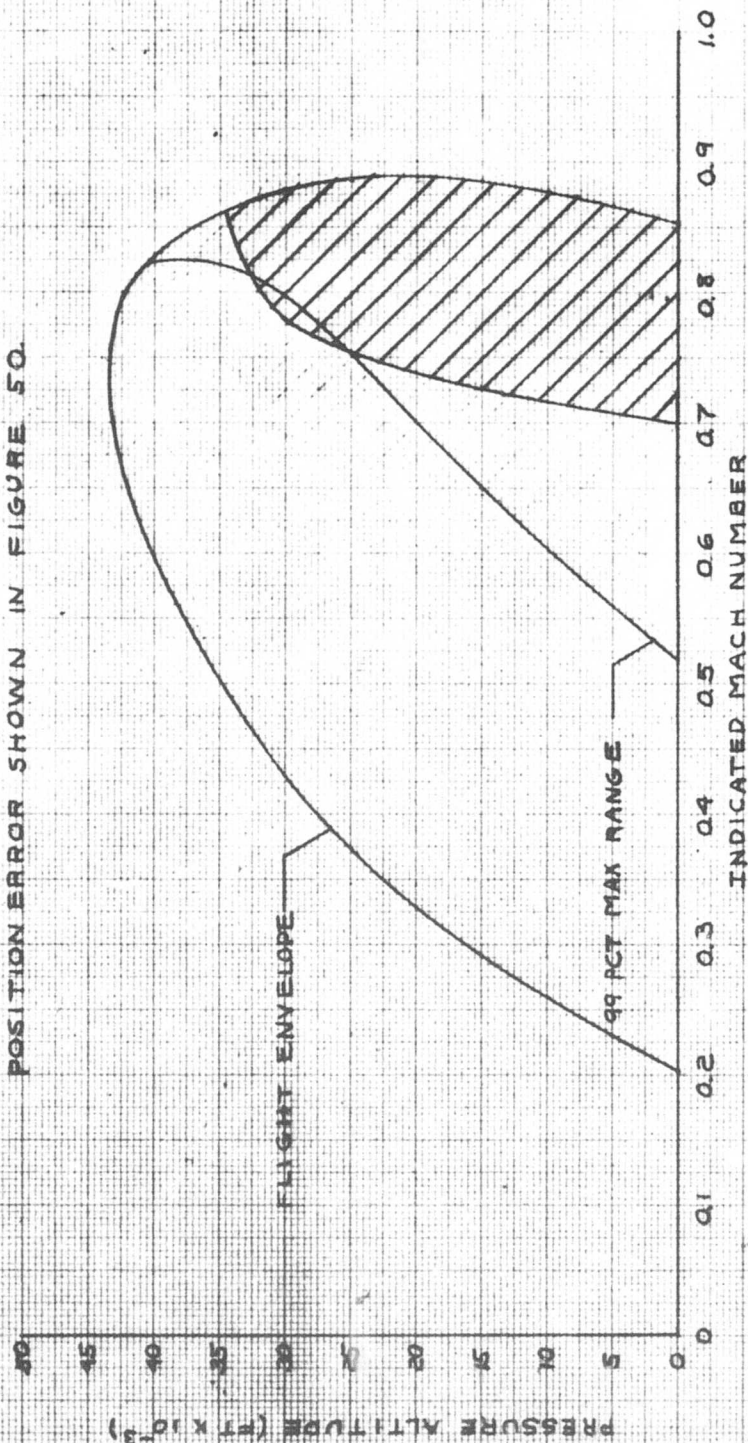
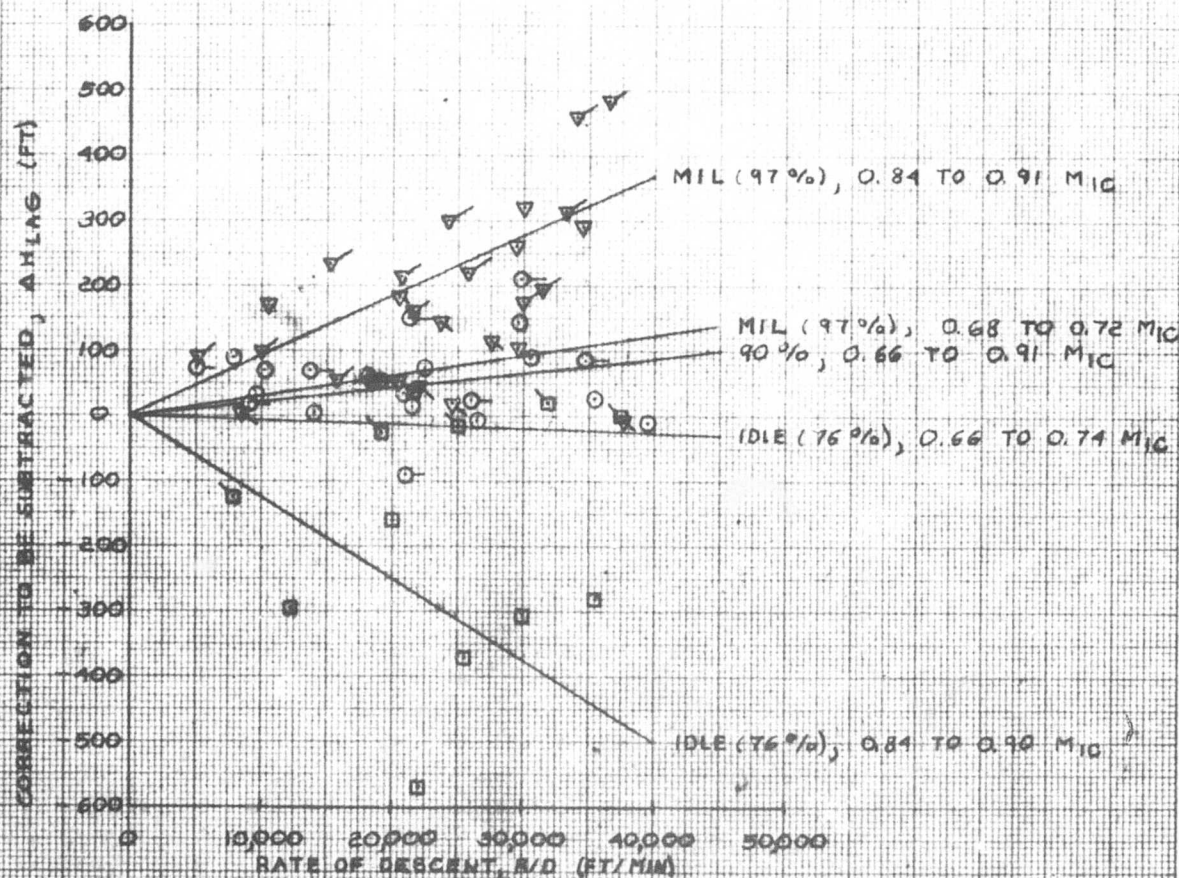


FIGURE 51 A-7E LEVELS 3 AND 4 FLIGHT REGIME, 30,000 FOOT REV J ADC CAMS

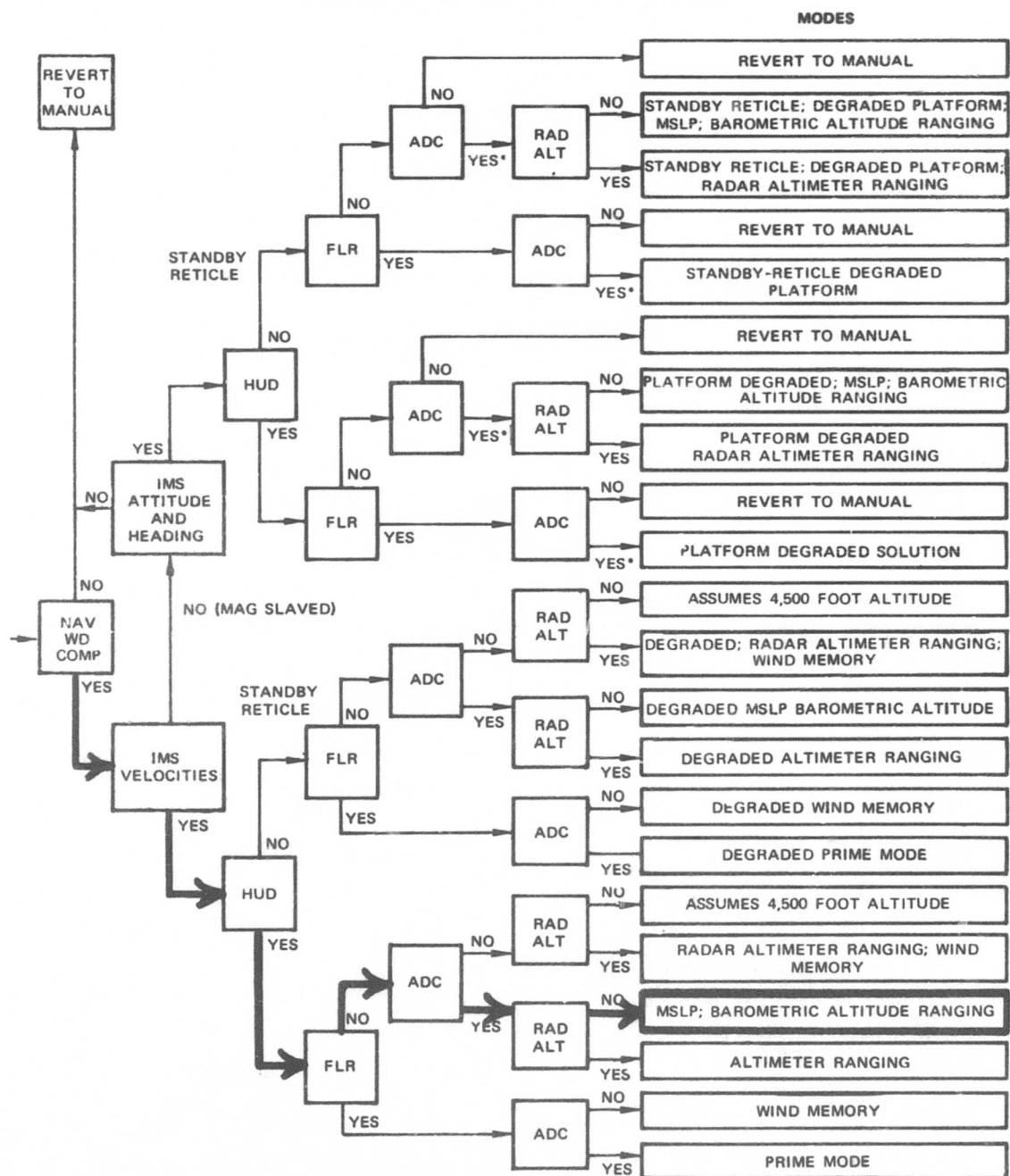
A-7D USAF S/N 70-973
REC MODEL 856W-566 PROBES
LOADING 1

SYMBOL	CORE SPEED	ALTIMETER	MODE	MACH NUMBER
▽	97%	AAU-19/A	RESET	0.84 TO 0.91
▽	97%	C-19	—	0.85 TO 0.91
○	90%	AAU-19/A	RESET	0.65 TO 0.91
○	90%	C-19	—	0.76 TO 0.86
□	76%	AAU-19/A	RESET	0.84 TO 0.90
□	76%	AAU-19/A	RESET	0.66 TO 0.74
△	97%	AAU-19/A	RESET	0.68 TO 0.72

- NOTES: 1. DATA OBTAINED BY THE RADAR METHOD
2. DATA OBTAINED AT 10,000 FT
3. C-19 ALTIMETER IS PNEUMATIC (STANDBY)
4. FAIRINGS OBTAINED FROM A LEAST SQUARES FIT



WEAPON DELIVERY BACKUP MODES FLOW DIAGRAM



*If Doppler fails or judged unreasonable, reverts to wind memory mode

78D099-02-70

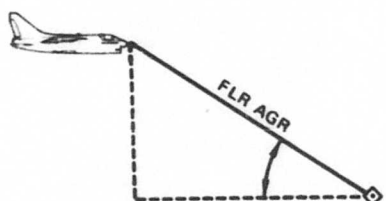
Figure 53 Weapon Delivery Backup Modes Flow Diagram

TARGET POSITION COMPUTATION

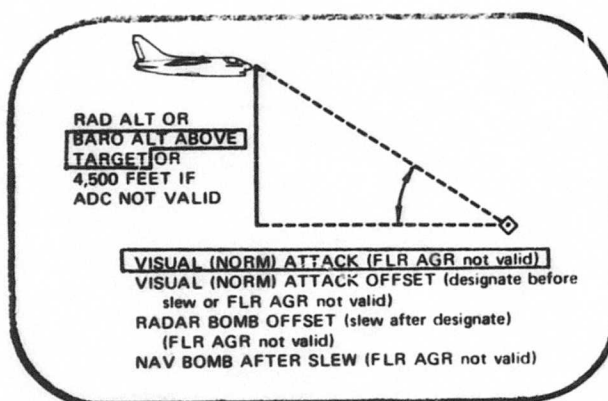


FUNDAMENTAL QUANTITIES RELATED TO TARGET POSITION

Using two inputs from valid sensor data, the NAV WD Computer derives the remaining two fundamental quantities for use in solving the weapon delivery problem; i.e., the ranging triangle. Methods for ranging solution, modes, and phase of attack in which they are used are as follows:

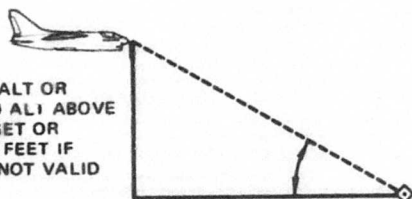


VISUAL (NORM) ATTACK
VISUAL (NORM) ATTACK OFFSET
RADAR BOMB OFFSET (slew after designate)
NAV BOMB (with slew)



RAD ALT OR
BARO ALT ABOVE
TARGET OR
4,500 FEET IF
ADC NOT VALID

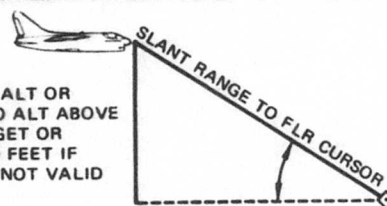
VISUAL (NORM) ATTACK (FLR AGR not valid)
VISUAL (NORM) ATTACK OFFSET (designate before
slew or FLR AGR not valid)
RADAR BOMB OFFSET (slew after designate)
(FLR AGR not valid)
NAV BOMB AFTER SLEW (FLR AGR not valid)



RAD ALT OR
BARO ALT ABOVE
TARGET OR
4,500 FEET IF
ADC NOT VALID

PRESENT POSITION AND
TARGET COORDINATES

RADAR BOMB (before slew)
RADAR BOMB OFFSET (before slew)
NAV BOMB (without slew)



RAD ALT OR
BARO ALT ABOVE
TARGET OR
4,500 FEET IF
ADC NOT VALID

RADAR BOMB (after slew)
RADAR BOMB OFFSET (after slew before designate)

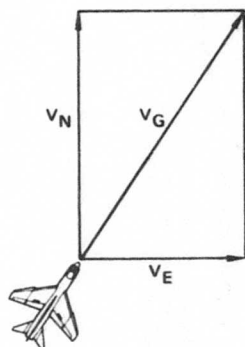
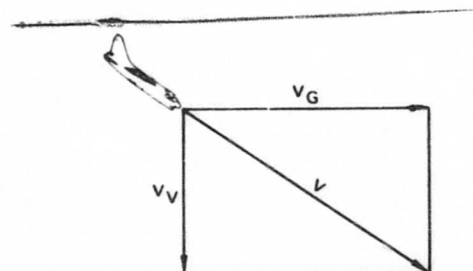
LEGEND

Inputs From Sensors ———
Derived Quantities - - - - -

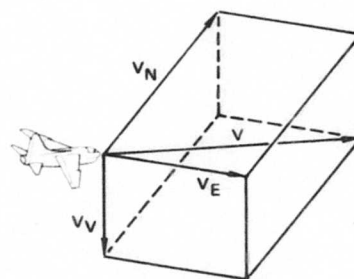
Figure 54 Target Position Computation

VELOCITY COMPUTATION

The velocity vector (V) of the aircraft represents the actual speed and direction of motion of the aircraft, relative to the surface of the earth. It is composed of a horizontal component which is true course/speed (ground track velocity, V_G) and a vertical component which is vertical velocity (V_V).



The ground track velocity (V_G) consists of north velocity (V_N) and east velocity (V_E).



The NAV WD Computer calculates these components of velocity using the valid data inputs of highest precedence available.

VELOCITY INPUT ORDER OF PRECEDENCE

IMS MODE	VELOCITY COMPONENT	FIRST	SECOND	THIRD	FOURTH
NORM OR INERTIAL	$V_N + V_E = V_G$	IMS (Doppler Damped)	IMS (Pure Inertial)	HEADING, ATTITUDE, AND DOPPLER	AOA, TAS, HEADING, ATTITUDE, AND MEMORY WIND
	V_V	IMS (Damped by Baro Alt)	AOA, PITCH ANGLE, AND V_G	AOA, PITCH ANGLE, AND TAS	
MAG SLAVE OR GRID	$V_N + V_E = V_G$	HEADING, ATTITUDE, AND DOPPLER	AOA, TAS, HEADING, ATTITUDE, AND MEMORY WIND		
	V_V	AOA, PITCH ANGLE, AND TAS			

Figure 55 Velocity Computation

VISUAL (NORM) ATTACK DELIVERY PROFILE

DIVE/DIVE-TOSS

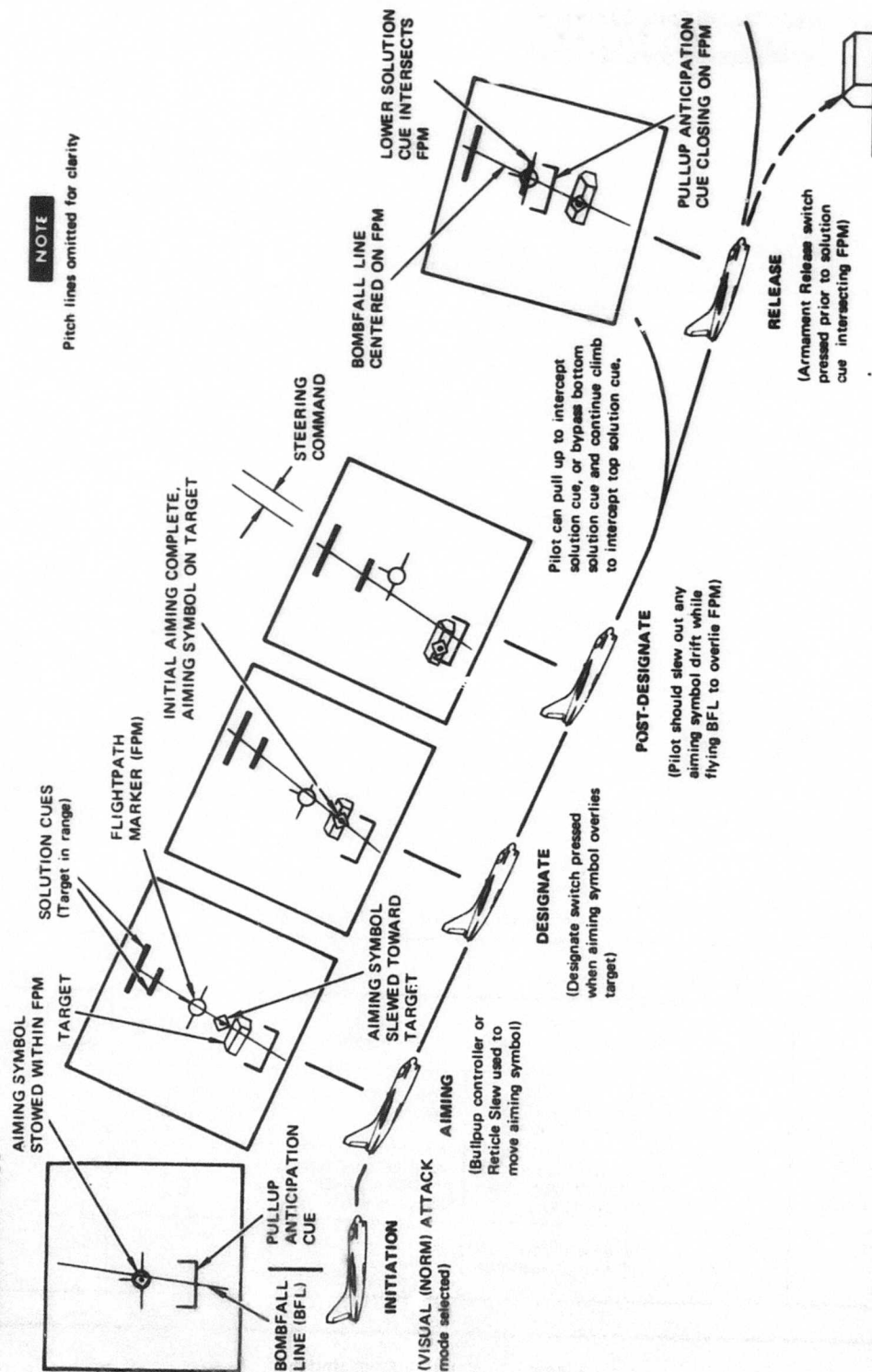
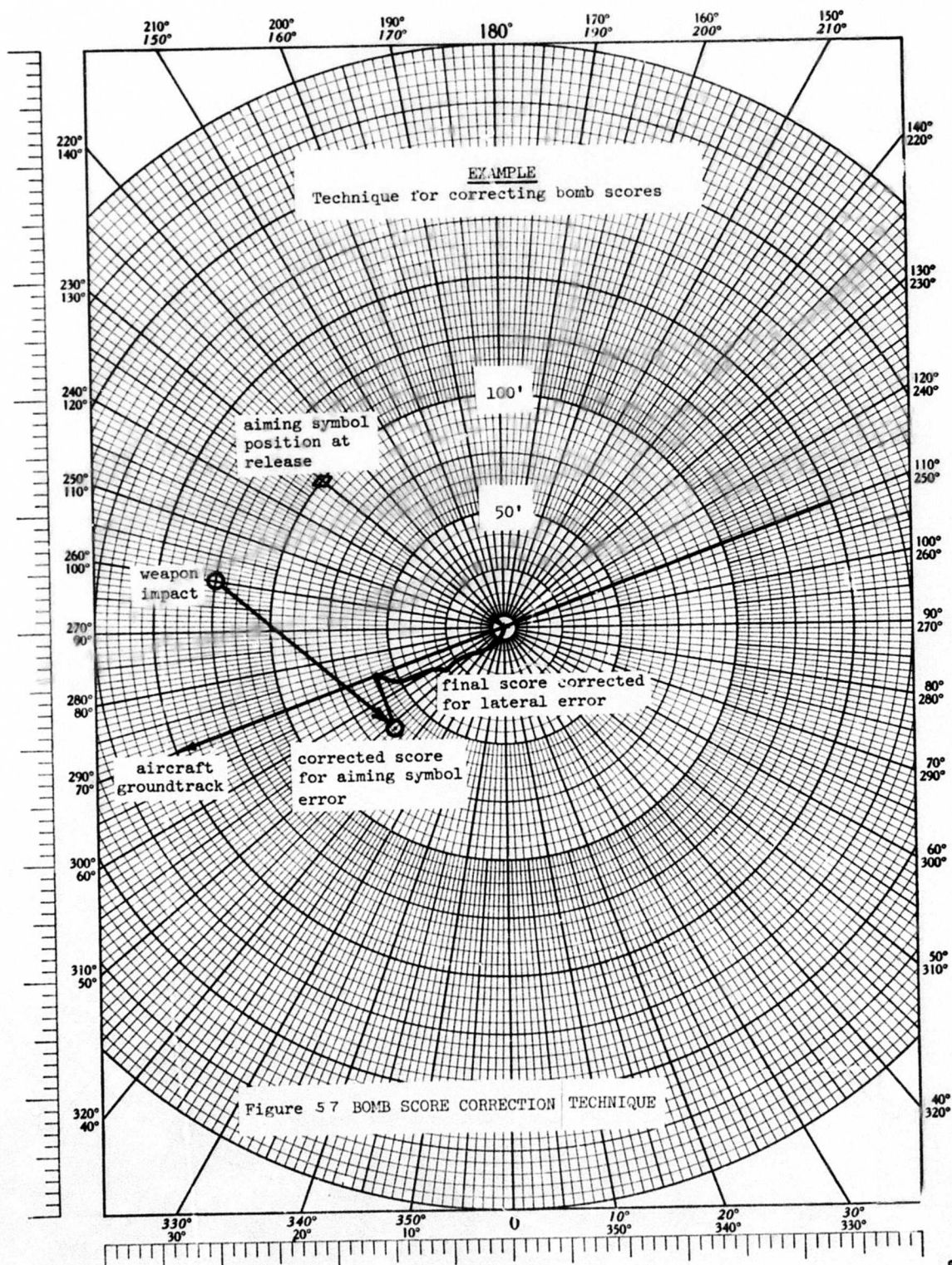
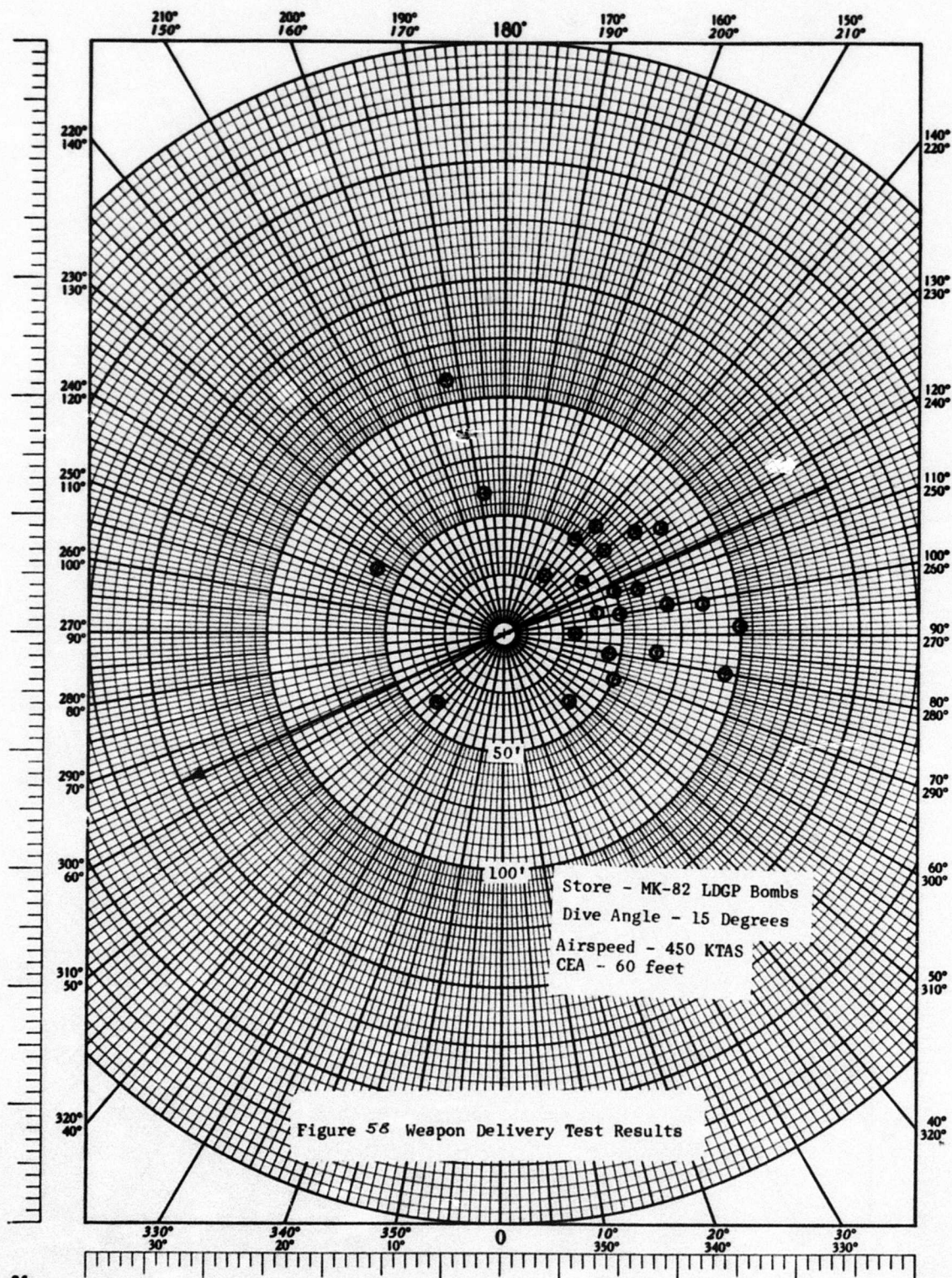
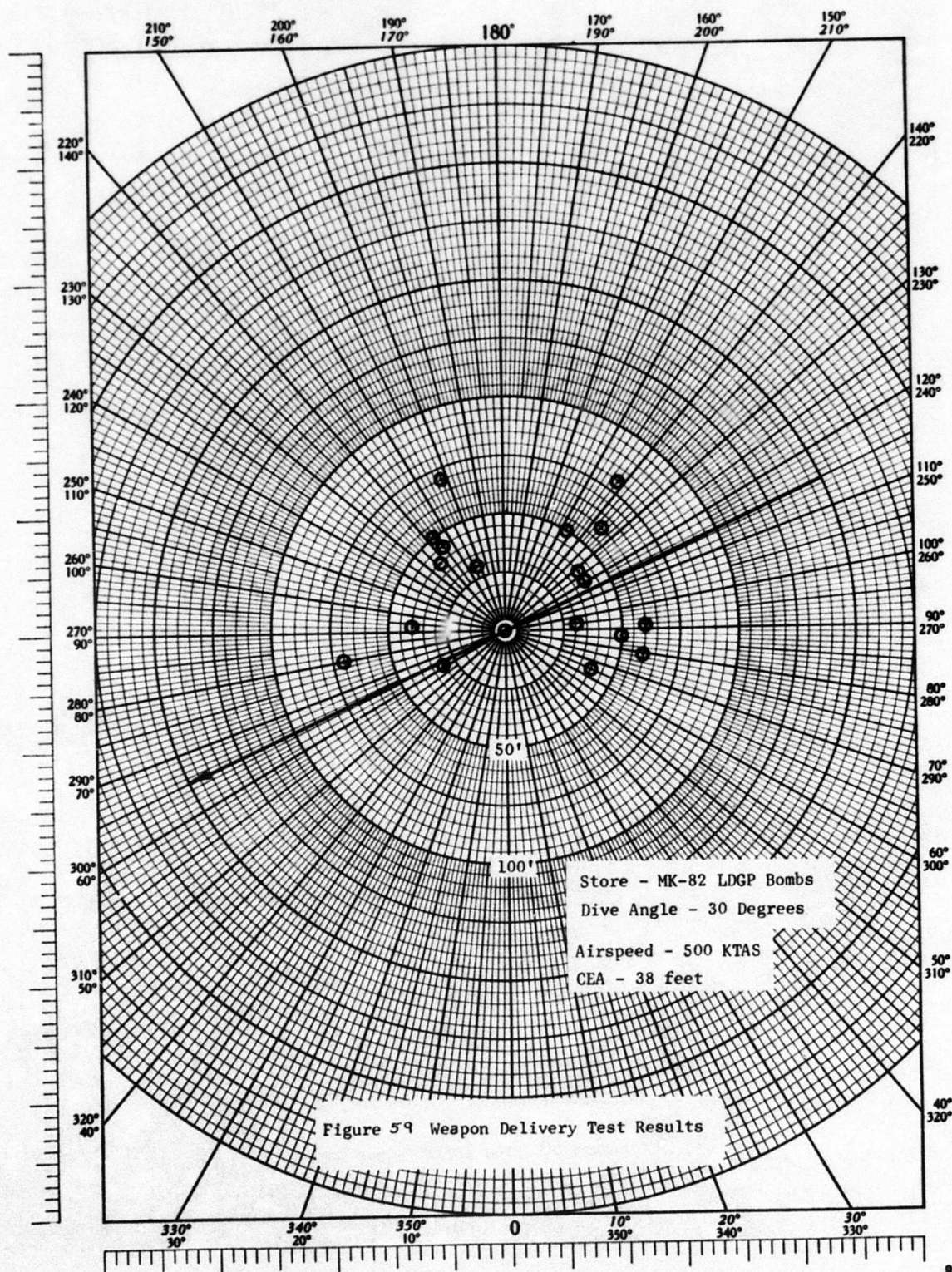


Figure 56 Weapon Delivery Profile









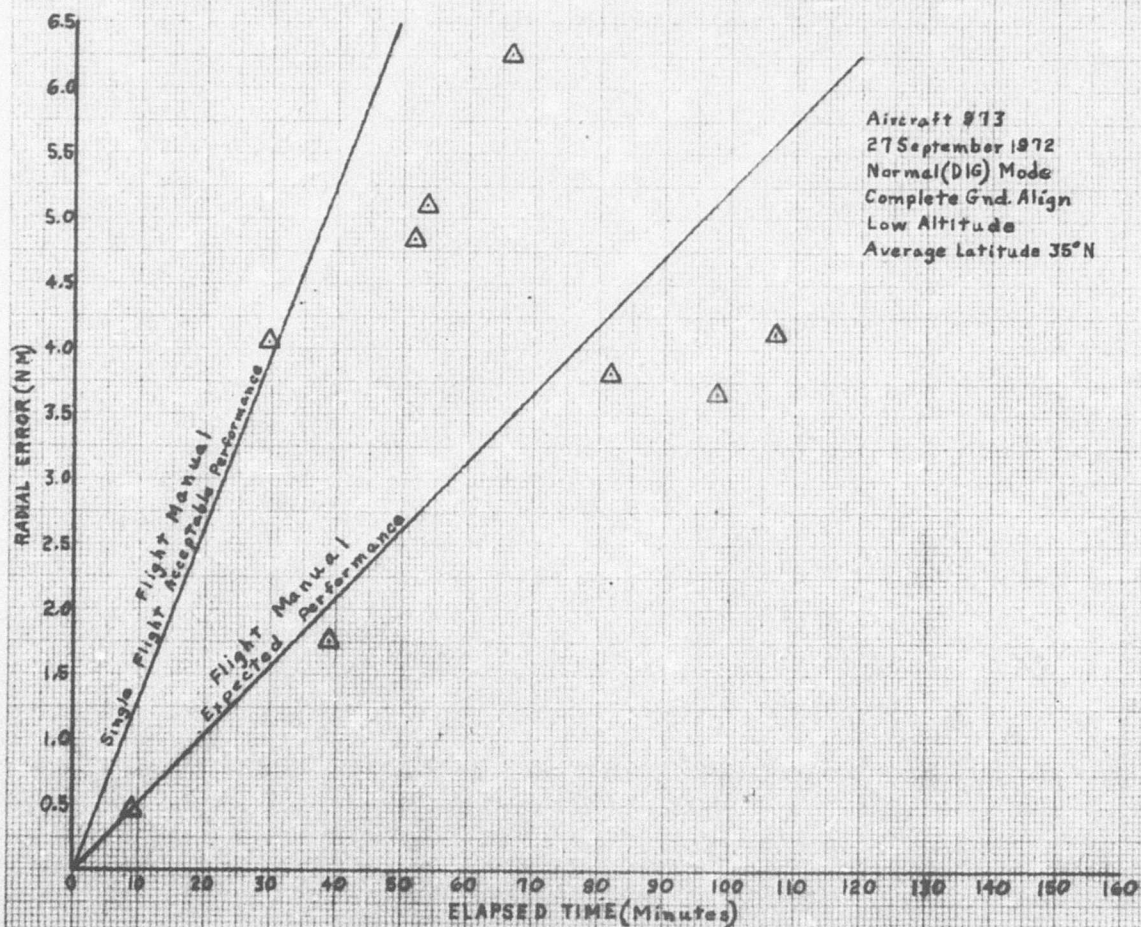
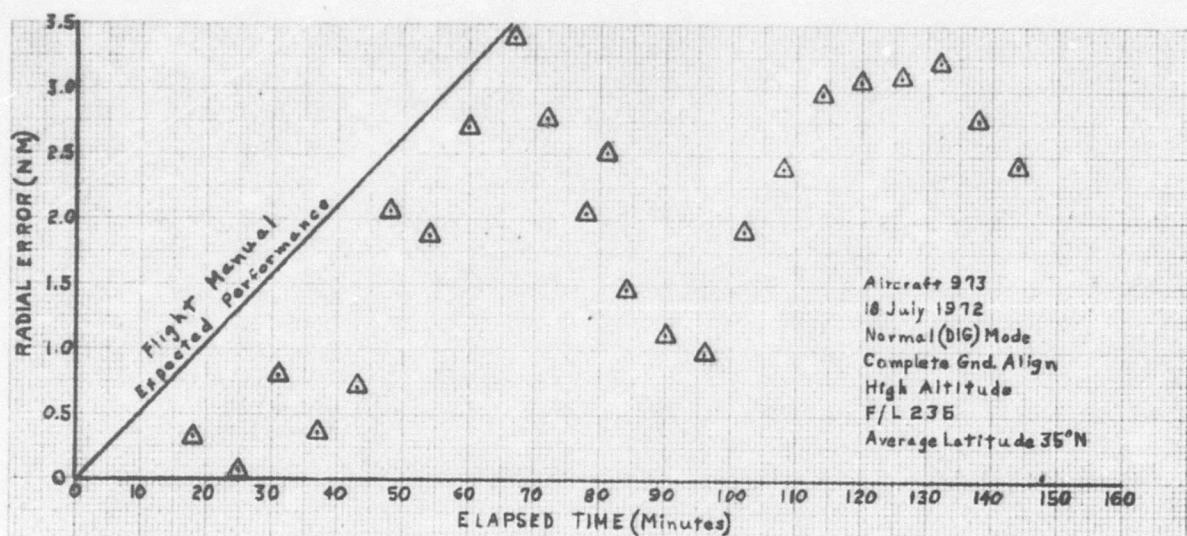


Figure 61 Navigation Accuracy

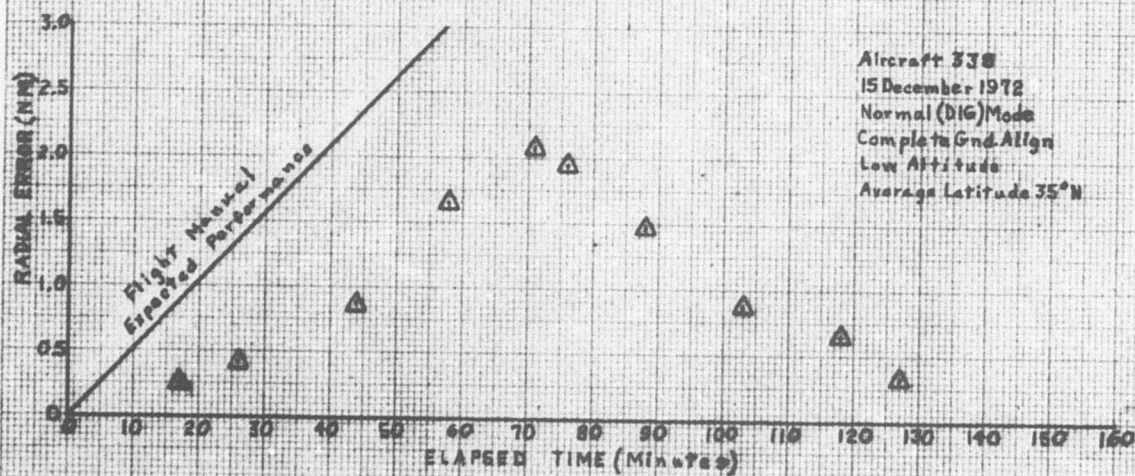
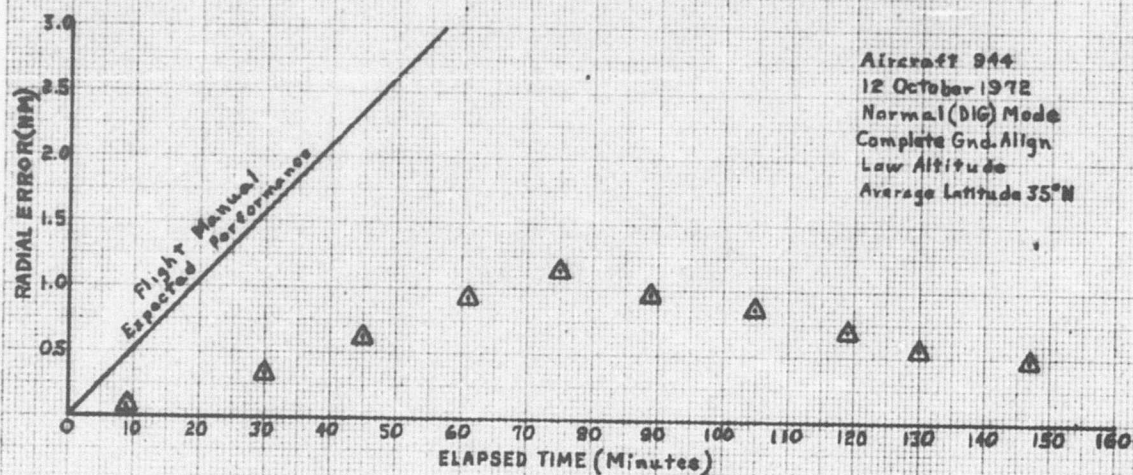


Figure 62 Navigation Accuracy

AIMS MODIFIED A-7D AIRCRAFT REC MODEL 856W-566 COMPENSATING PITOT-STATIC PROBES LOADING 1

SYMBOL	ALTITUDE (FEET)
Δ	2,300
▽	10,000
○	20,000
◊	30,000
◻	40,000

- NOTES: 1. DATA WAS OBTAINED IN STABILIZED LEVEL FLIGHT IN THE CRUISE CONFIGURATION.
2. DASHED FAIRINGS WERE OBTAINED FROM FIGURES 16, 22, AND 28 FOR A-7D'S 973, 944, AND 338, RESPECTIVELY.
3. SOLID FAIRINGS WERE OBTAINED BY APPLYING THE CORRECTIONS OF TABLE 6 TO THE SOLID (RESET) FAIRINGS.

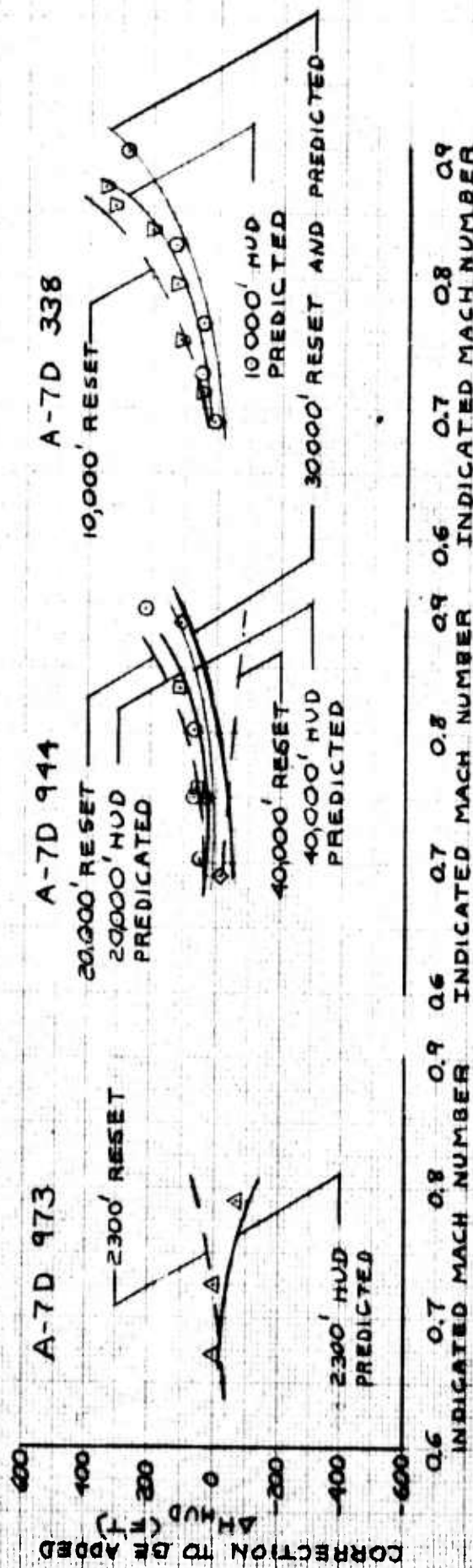


FIGURE 63 HUD POSITION ERROR CORRECTION

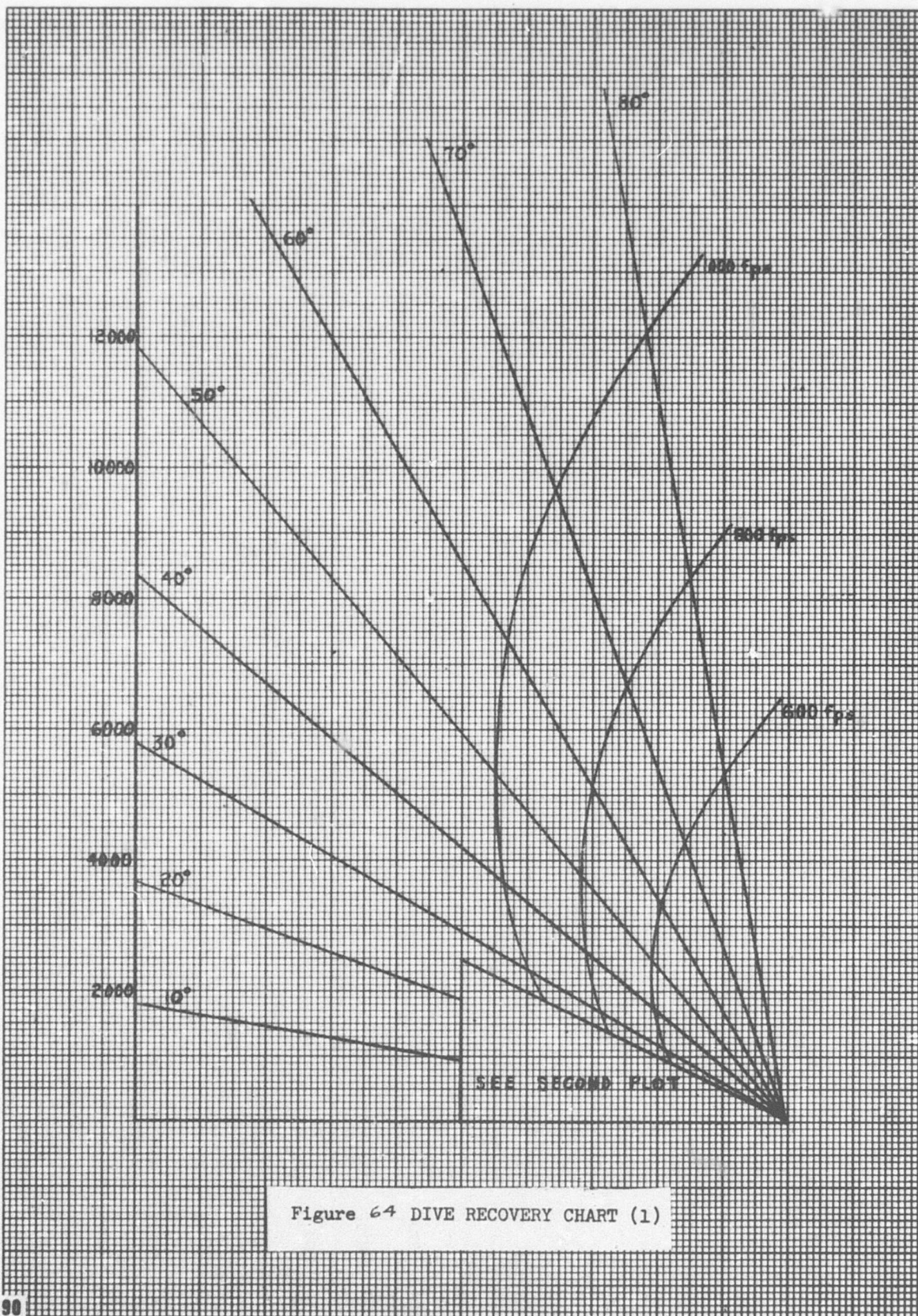


Figure 64 DIVE RECOVERY CHART (1)

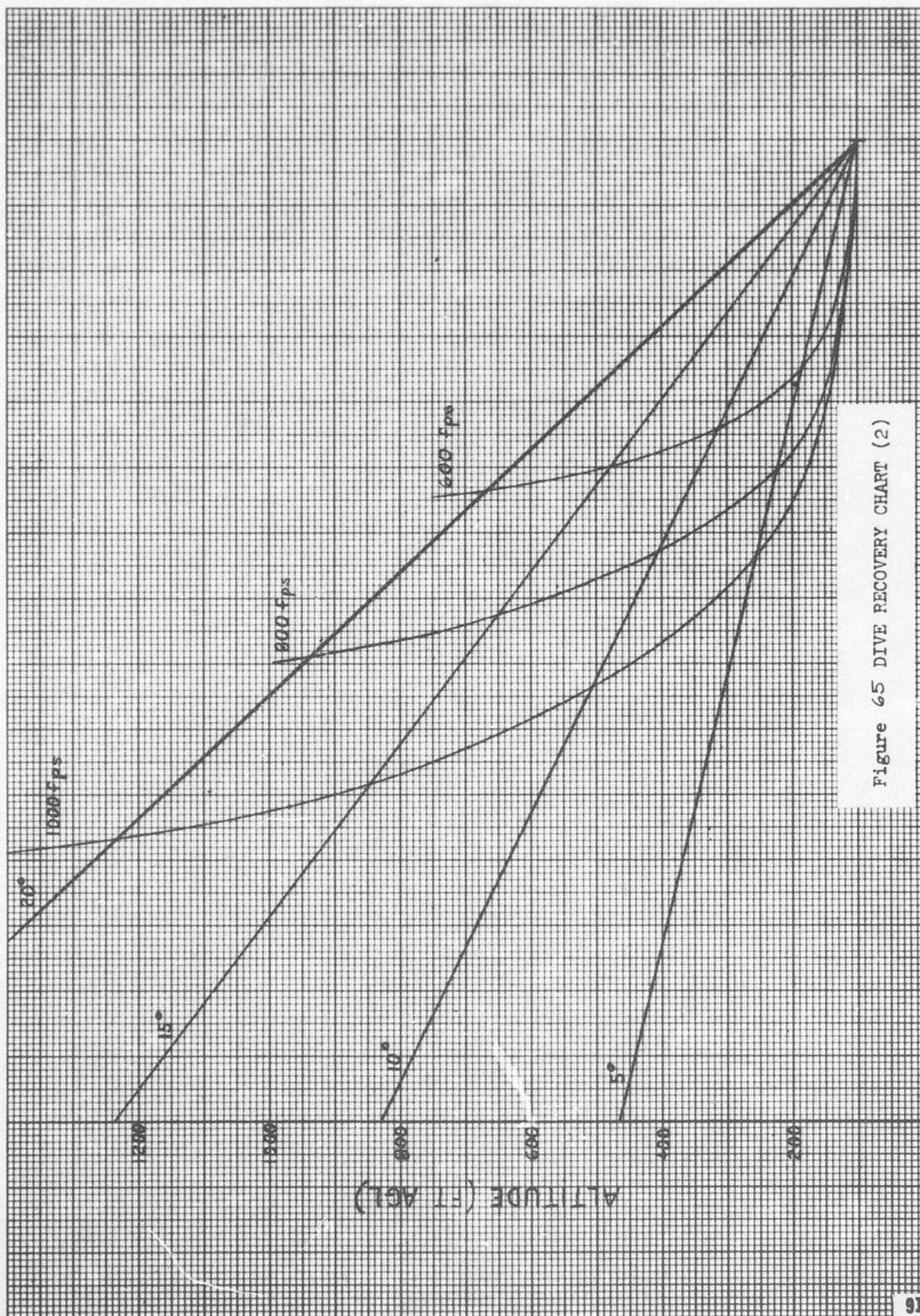


Figure 65 DIVE RECOVERY CHART (2)

A-7D USAF S/N 71-338
REC MODEL 856W-566 COMPENSATING PITOT-STATIC PROBES
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
△	2,300	TOWER FLY-BY	POWER APPROACH
△	2,300	TOWER FLY-BY	CRUISE
▽	10,000	PAGE	CRUISE
◇	20,000	PAGE	CRUISE
○	30,000	PAGE	CRUISE
○	35,000	PAGE	CRUISE

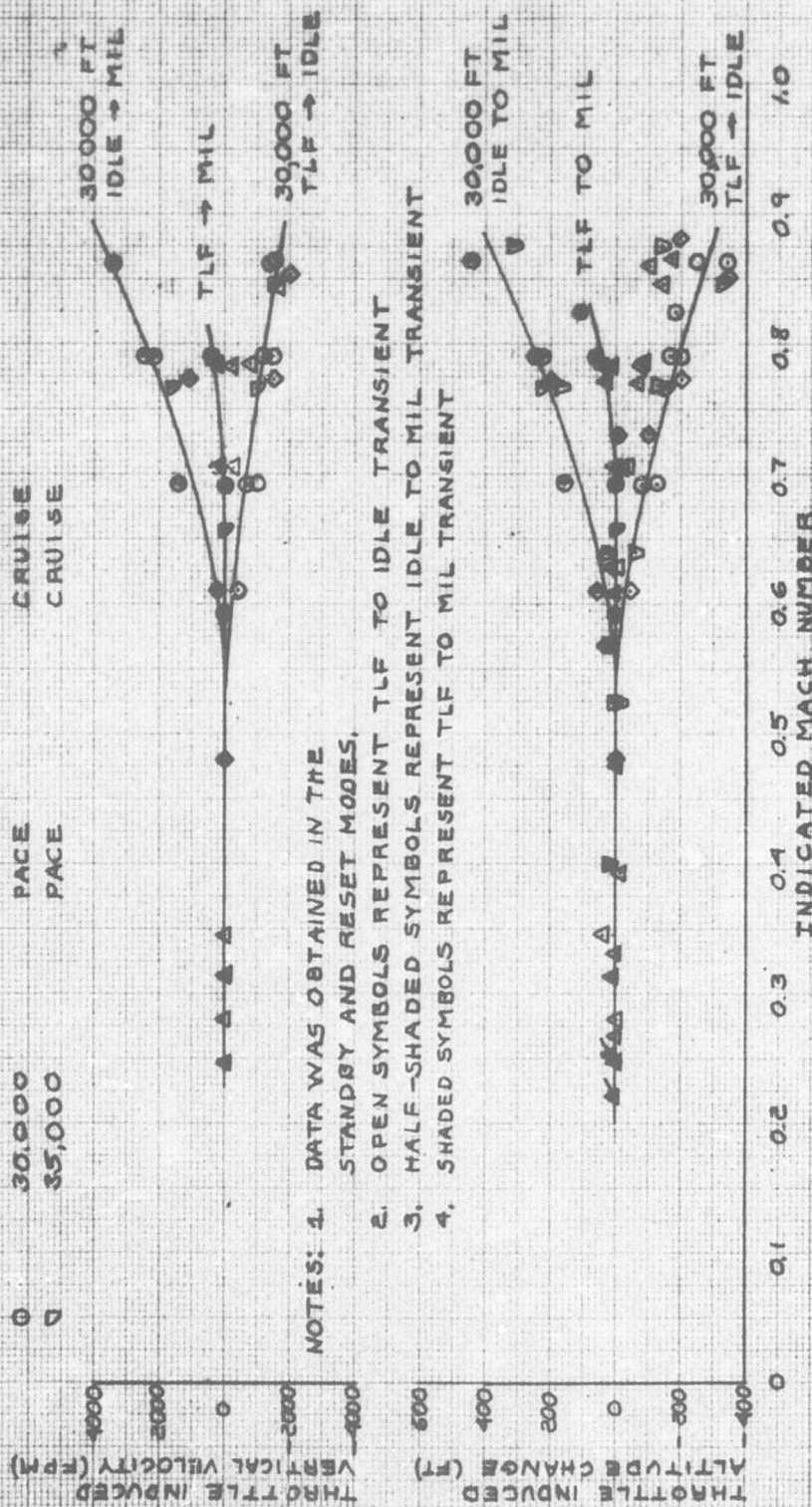


FIGURE 66 THROTTLE INDUCED TRANSIENTS

A-7D USAF S/N 70-973
 REC MODEL 856W-546 COMPENSATING PITOT-STATIC PROBES
 LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
V	10,000	PACE	CRUISE
Q	30,000	PACE	CRUISE

- NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
 2. DATA OBTAINED BY THE AH METHOD
 3. MELTED PROBE COVER PLASTIC ON THE PROBES
 4. FAIRINGS OBTAINED FROM FIGURE 12

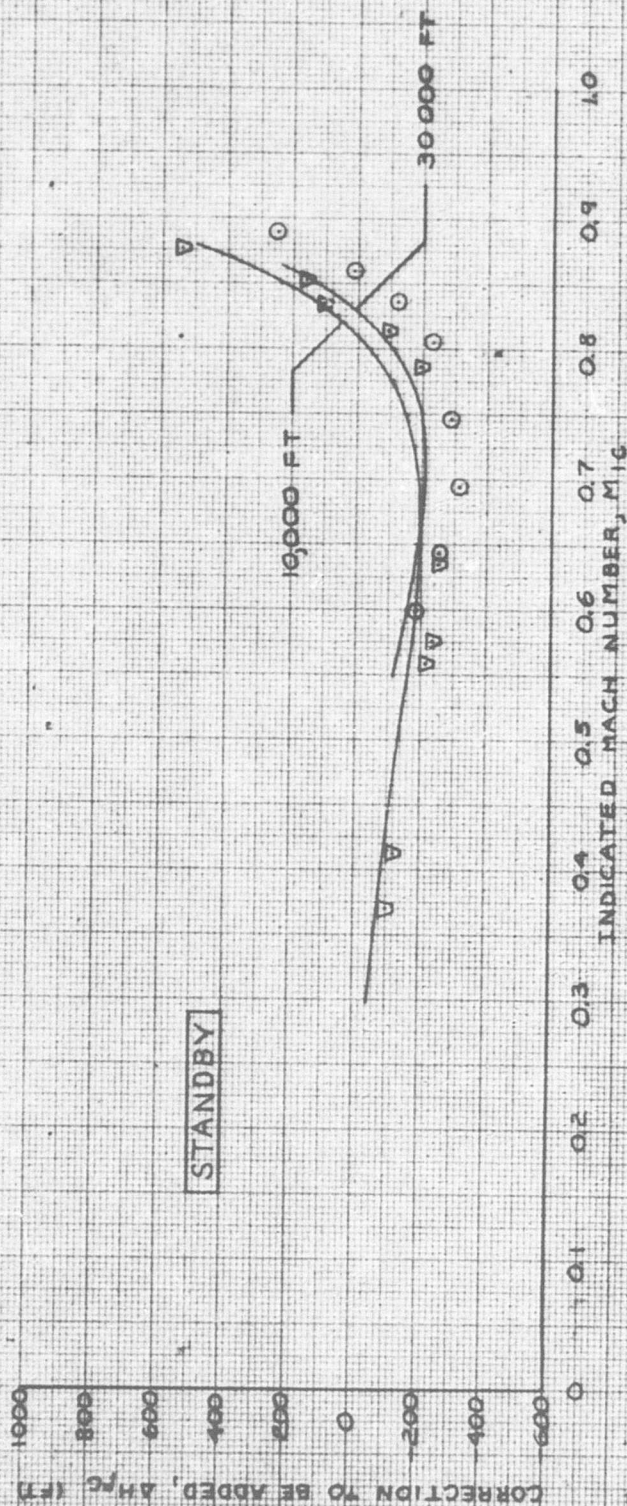


FIGURE 67 EFFECT OF MELTED PLASTIC ON AH₁₆

REC MODEL 856W-556 COMPENSATING PITOT-STATIC PROBES
A-7D USAF S/N 70-973
LOADING 1

SYMBOL	ALTITUDE (FT)	METHOD	CONFIGURATION
▽	10,000	PACE	CRUISE
◇	20,000	PACE	CRUISE
○	30,000	PACE	CRUISE
▽	35,000	PACE	CRUISE
□	40,000	PACE	CRUISE

- NOTES: 1. AAU-19/A ALTIMETER IN STANDBY
2. DATA OBTAINED BY THE ΔH METHOD
3. PLASTIC TAPE ON THE PROBES
4. FAIRINGS OBTAINED FROM FIGURE 12

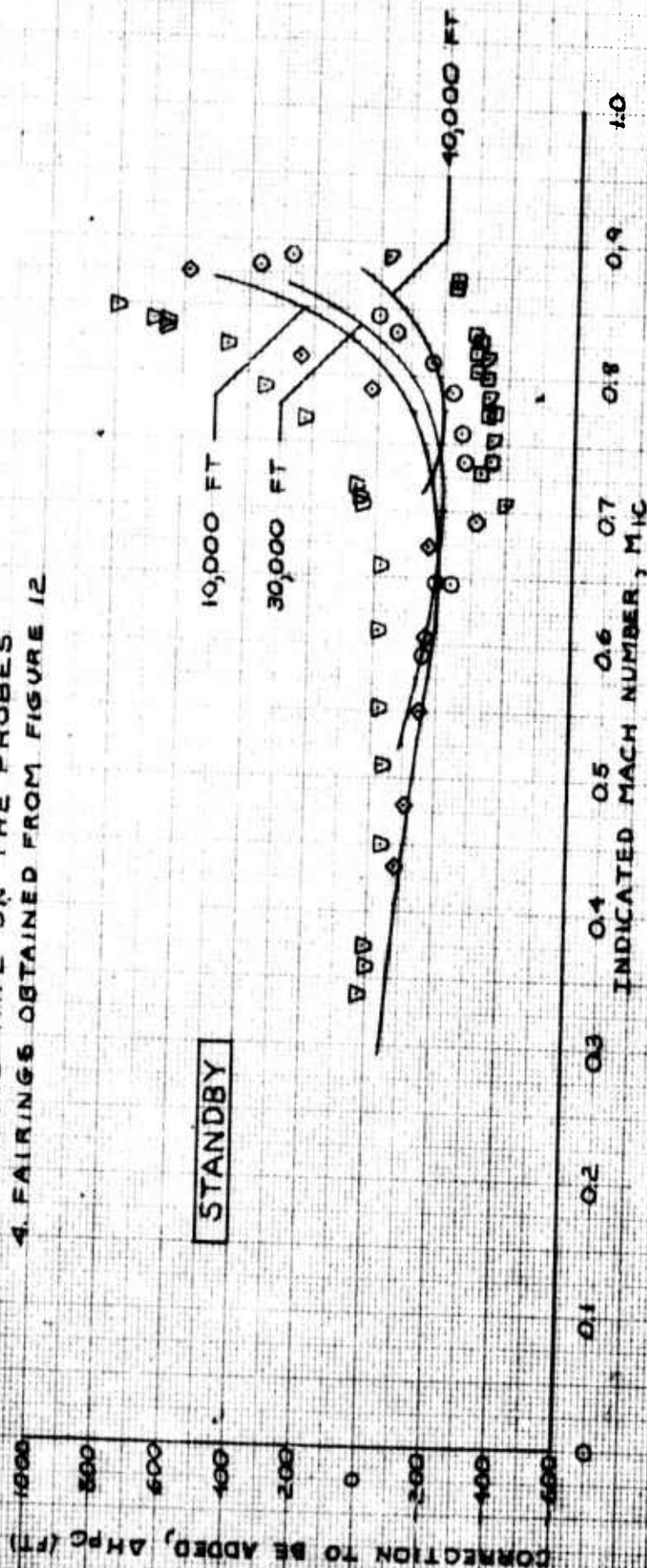


FIGURE 68 EFFECT OF PLASTIC TAPE ON ΔH PC

APPENDIX

ERROR ANALYSIS AND FLIGHT LOG

ERROR ANALYSIS

The DOD AIMS Level 3 criterion for altitude reporting systems requires that the cockpit altitude indication be within 250 feet of the correct pressure altitude (reference 2). This means that the absolute value of the sum of residual position error in the RESET mode, ΔH plus the total random system error, δH_{sys} , must be less than 250 feet. The Level 3 criterion may be defined by the following expression:

$$|\Delta H \pm \delta H_{\text{sys}}| \leq 250 \text{ feet}$$

In AIMS reports on previously tested aircraft, the AIMS modification was considered to be acceptable if the residual (RESET) position error was less than ± 125 feet. An implied allowance of ± 125 feet was made for random system errors.

The results of the AIMS Level 1 testing indicated that position error variation between sea level and 40,000 feet would probably exceed ± 150 feet for the best probe developed (reference 1). The error analysis was made for the AIMS-modified A-7D aircraft to determine the total random system error, and in turn, determine the allowable position error in the RESET mode which would satisfy the Level 3 criterion.

The error analysis determined total random system error by the root-sum-square method. That is, the total random system error was equal to the square root of the sum of the squares of the individual component deviations from the mean of a normal distribution. The root-sum-square technique yields a total random system error which represents a three-sigma deviation from the mean of the A-7D fleet (99.7 percent of the fleet would fall within a three-sigma deviation). The approach used in the error analysis was to determine the errors associated with pitot-static system calibration, the ADC, and the AAU-19/A altimeter.

Overall Position Error Uncertainty

The overall position error uncertainty (δH_{pc}) of pitot-static system calibration error is given by the following expression:

$$\delta H_{\text{pc}}^2 = \Delta H_{\text{cal}}^2 + \Delta H_{\text{a/c}}^2 + \Delta H_{\text{p}}^2$$

where

$\Delta H_{\text{a/c}}$ = position error variation between different test aircraft caused by minor variations in the probe, installation, aircraft external geometry and, for the A-7D, engine air-flow (ft)

ΔH_{cal} = position error variation due to pacer and tower fly-by techniques (ft)

ΔH_{p} = position error variation due to pitot-static probe design and manufacturing (ft)

The variation of ΔH_{cal} , ΔH_p , and $\Delta H_{a/c}$ with altitude is shown in table X. The variation of ΔH_{cal} is attributed to pacer and tower fly-by calibration techniques (reference 9). Pitot-static probe tolerances are normally expressed in terms of position error pressure coefficient, $\Delta P/Q_{cic}$.

Table X
VARIATION OF ΔH_{cal} , ΔH_p AND $\Delta H_{a/c}$ WITH ALTITUDE

Pressure Altitude (ft)	ΔH_{cal} (ft)	ΔH_p (ft)	$\Delta H_{a/c}$ (ft)
2,300	+26 (Tower fly-by)	+25.0	+85
10,000	+36 (Pace)	+25.0	+70
20,000	+46 (Pace)	+25.0	+50
30,000	+65 (Pace)	+25.0	+25
40,000	+95 (Pace)	+25.0	0

The value of ΔH_p presented represents the worst error expected for any altitude (reference 6). The variation of position error among A-7D aircraft, $\Delta H_{a/c}$, as presented in table X, was estimated from the fairings of ΔH_{pc} on figures 12, 18, 24, and 30. Due to the slope of the ΔH_{pc} curves above 0.80 indicated Mach number, small airspeed errors may produce significant uncertainty in ΔH_{pc} . For this reason, the values for $\Delta H_{a/c}$ were obtained at indicated Mach numbers below 0.80. The possible contributions of ΔH_{cal} , ΔH_p , and altimeter calibration were considered in estimating the values of $\Delta H_{a/c}$ presented in table X. The effect of $\Delta H_{a/c}$ on δH_{pc} is shown in table XI.

Table XI
OVERALL POSITION ERROR UNCERTAINTY, δH_{pc}

Pressure Altitude (ft)	δH_{pc} (ft)	
	$\Delta H_{a/c} = 0$	With A-7D $\Delta H_{a/c}^1$
2,300	+36.1	+82.3
10,000	+43.8	+81.2
20,000	+52.3	+72.5
30,000	+69.6	+74.0
40,000	+98.2	+98.2

¹The values of $\Delta H_{a/c}$ used in computing these values of δH_{sys} were taken from table X.

Air Data Computer Design Tolerance

The ADC design tolerance (δH_{ADC}) is defined by:

$$\delta H_{ADC}^2 = \Delta H_T^2 + \Delta H_{vib}^2 + \Delta H_{cam}^2$$

where

ΔH_T = ADC temperature design tolerance (ft)

ΔH_{vib} = ADC vibration design tolerance (ft)

ΔH_{cam} = ADC cam positioning design tolerance and cam manufacturing tolerance (ft)

The variance of ΔH_T is shown in table XII, and ΔH_{vib} is shown in table XIII (reference 10). The maximum cam positioning error tolerance (ΔH_{cam}) is +50 feet (reference 10). Combining ΔH_T , ΔH_{vib} , and ΔH_{cam} yields the values for δH_{ADC} shown in table XIV.

Table XII

ADC TEMPERATURE DESIGN TOLERANCE, ΔH_T

Pressure Altitude (ft)	Operating Environmental Temperature	
	ΔH_T (ft)	
	-54 deg C	10 to 50 deg C
2,300	+46.9	+25.0
10,000	+70.0	+25.0
20,000	+100.0	+50.0
30,000	+130.0	+75.0
40,000	+160.0	+100.0

Table XIII

ADC VIBRATION DESIGN TOLERANCE, ΔH_{vib}

Pressure Altitude (ft)	Operating Environmental Temperature	
	ΔH_{vib} (ft)	
	-54 deg C	10 to 50 deg C
2,300	+23.5	+12.5
10,000	+35.0	+12.5
20,000	+50.0	+25.0
30,000	+65.0	+37.5
40,000	+80.0	+50.0

Table XIV

ADC DESIGN TOLERANCE, δH_{ADC}

Pressure Altitude (ft)	Operating Environmental Temperature	
	δH_{ADC} (ft)	
	-54 deg C	10 to 50 deg C
2,300	+72.5	+57.3
10,000	+92.8	+57.3
20,000	+122.5	+75.0
30,000	+153.7	+97.6
40,000	+185.6	+122.5

Total Random System Error

The total random system error, δH_{sys} , is defined by:

$$\begin{aligned}\delta H_{\text{sys}}^2 &= \Delta H_{\text{cal}}^2 + \Delta H_{\text{p}}^2 + \Delta H_{\text{a/c}}^2 + \Delta H_{\text{T}}^2 + \Delta H_{\text{vib}}^2 + \Delta H_{\text{cam}}^2 + \delta H_{\text{alt}}^2 \\ &= \delta H_{\text{pc}}^2 + \delta H_{\text{ADC}}^2 + \delta H_{\text{alt}}^2\end{aligned}$$

where

δH_{alt} = AAU-19/A altimeter design tolerance in the RESET mode.

A value of +30 feet was used for δH_{alt} (reference 11). The total random system error as a function of altitude and ADC operating environment temperature is shown in table XV.

Table XV

TOTAL A-7D RANDOM SYSTEM ERROR, δH_{sys}

Pressure Altitude (ft)	δH_{sys} (ft)			
	$\Delta H_{\text{a/c}} = 0$		A-7D $\Delta H_{\text{a/c}}^1$	
	-54 deg C	10 to 50 deg C	-54 deg C	10 to 50 deg C
2,300	+86.3	+74.1	+121.1	+112.7
10,000	+107.3	+78.1	+127.0	+103.8
20,000	+136.5	+96.2	+145.4	+108.5
30,000	+171.4	+123.6	+173.2	+126.5
40,000	+212.2	+159.8	+212.2	+159.8

¹ The values of $\Delta H_{\text{a/c}}$ used in computing these values of δH_{sys} were taken from table X.

Allowable Position Error in Reset

As stated earlier, the Level 3 criterion for all aircraft requires that the absolute value of $\Delta H \pm \delta H_{\text{sys}}$ be less than 250 feet. The maximum allowable values of residual position error correction in the RESET mode (ΔH) for the A-7D range from +90.2 feet at 40,000 feet altitude to +176.5 feet at sea level when $\Delta H_{\text{a/c}}$ is zero and the ADC is operating in the mid-temperature range (figure 7, case 1).

Above 5,000 feet, it is probable that the operating environmental temperature of the ADC would fall between 10 degrees and -54 degrees C. For this case, and using the estimated variation of position error among A-7D aircraft, the allowable residual position error is +133.5 feet at sea level and +57.5 feet at 40,000 feet pressure altitude (figure 7, case 2). The two cases were used to evaluate the A-7D AIMS modification against the Level 3 requirement.

FLIGHT LOG

Date	Flight ¹	Flight Time (hr)	Loading ²	Probes	Test
23 Feb 72	001	1.5	1	Rev J	Airspeed calibration
3 Mar 72	002	2.2	1	Rev J	Tower fly-by and airspeed calibration
9 Mar 72	003	1.7	1	Rev J	Airspeed calibration
9 Mar 72	004	1.3	1	Rev J	Tower fly-by
13 Mar 72	005	1.8	5	Rev J	Tower fly-by and airspeed calibration
13 Mar 72	006	1.3	5	Rev J	Airspeed calibration
11 Feb 72	101	2.3	1	Rev J	Tower fly-by and airspeed calibration
11 Feb 72	102	2.1	1	Rev J	Tower fly-by and airspeed calibration
14 Feb 72	103	1.8	1	Rev J	Airspeed calibration
26 Feb 72	104	2.0	1	Rev J	Water spray tests
28 Feb 72	105	2.0	1	Rev J	Tower fly-by and airspeed calibration
29 Feb 72	106	1.6	1	Rev J	Airspeed calibration
16 Mar 72	107	2.0	1	W-546	Tower fly-by
17 Mar 72	108	2.2	1	W-546	Tower fly-by and airspeed calibration
20 Mar 72	109	1.3	1	W-546	Airspeed calibration
16 Mar 72	110	2.0	1	W-546	Tower fly-by
16 May 72	111	2.2	1	W-546	Lag investigation and airspeed calibration
17 May 72	112	1.7	1	W-546	Lag and sideslip investigation
17 May 72	113	1.8	1	W-546	Lag investigation and airspeed calibration
18 May 72	114	1.7	1	W-546	Lag investigation and airspeed calibration
22 May 72	115	1.7	1	W-546	Lag, sideslip investigation, airspeed calibration
23 May 72	116	1.9	1	W-546	Lag investigation and airspeed calibration
23 May 72	117	1.8	1	W-546	Lag investigation and airspeed calibration
31 May 72	118	1.4	1	W-546	Lag investigation and airspeed calibration
2 Jun 72	119	1.7	1	W-546	Lag investigation
6 Jun 72	120	0.7	1	W-546	Lag investigation
9 Jun 72	121	1.7	1	W-546	Lag investigation and airspeed calibration
27 Jun 72	122	2.2	1	W-546	Tower fly-by
12 Jul 72	123	1.7	1	W-546	Simulated weapon delivery
13 Jul 72	124	1.1	3	W-546	Weapon delivery
13 Jul 72	125	1.3	3	W-546	Weapon delivery
14 Jul 72	126	1.3	3	W-546	Weapon delivery
14 Jul 72	127	1.8	3	W-546	Weapon delivery
17 Jul 72	128	1.7	1	W-546	Lag investigation
17 Jul 72	129	1.7	3	W-546	Weapon delivery
18 Jul 72	130	1.4	3	W-546	Weapon delivery
18 Jul 72	131	2.6	2	W-546	Navigation accuracy
19 Jul 72	132	2.2	2	W-546	Navigation accuracy
24 Jul 72	133	1.4	3	W-546	Weapon delivery
24 Jul 72	134	1.1	3	W-546	Weapon delivery
25 Jul 72	135	1.1	3	W-546	Weapon delivery
27 Jul 72	136	0.3	3	W-546	Weapon delivery
1 Aug 72	137	1.0	1	W-546	Lag investigation
1 Aug 72	138	1.3	3	W-546	Weapon delivery
2 Aug 72	139	1.3	3	W-546	Weapon delivery
3 Aug 72	140	1.0	3	W-546	Weapon delivery
3 Aug 72	141	1.0	3	W-546	Weapon delivery
7 Aug 72	142	1.0	3	W-546	Weapon delivery and HUD accuracy
7 Aug 72	143	1.0	3	W-546	Weapon delivery

FLIGHT LOG (Continued)

Date	Flight ¹	Flight Time (hr)	Loading ²	Probes	Test
1 Sep 72	144	1.3	1	W-5&6	Wind direction and HUD accuracy
21 Sep 72	145	1.0	4	W-5&6	Weapon delivery
21 Sep 72	146	1.0	4	W-5&6	Weapon delivery
25 Sep 72	147	1.3	1	W-5&6	Pullup command mission
27 Sep 72	148	2.3	2	W-5&6	Navigation accuracy
20 Feb 72	149	2.2	1	W-5&6	Airspeed calibration, throttle transients
3 Jul 72	201	1.8	2	W-5&6	Tower fly-by and airspeed calibration
3 Jul 72	202	1.4	2	W-5&6	Airspeed calibration
6 Jul 72	203	0.7	1	W-5&6	Tower fly-by, throttle transients
16 Aug 72	204	2.0	1	W-5&6	Tower fly-by and airspeed calibration
18 Aug 72	205	1.4	1	W-5&6	Tower fly-by
21 Aug 72	206	1.1	3	W-5&6	Weapon delivery
21 Aug 72	207	2.0	1	W-5&6	Tower fly-by and HUD accuracy
22 Aug 72	208	1.6	1	W-5&6	Tower fly-by and HUD accuracy
23 Aug 72	209	1.7	1	W-5&6	Tower fly-by
29 Aug 72	210	1.5	1	W-5&6	Tower fly-by
29 Aug 72	211	1.6	1	W-5&6	Airspeed calibration
3 Oct 72	212	1.0	3	W-5&6	Weapon delivery
3 Oct 72	213	1.0	3	W-5&6	Weapon delivery
4 Oct 72	214	1.0	3	W-5&6	Weapon delivery
4 Oct 72	215	1.1	3	W-5&6	Weapon delivery
5 Oct 72	216	1.3	3	W-5&6	Weapon delivery
6 Oct 72	217	1.0	4	W-5&6	Weapon delivery
6 Oct 72	218	1.0	4	W-5&6	Weapon delivery
10 Oct 72	219	2.0	1	W-5&6	HUD accuracy
12 Oct 72	220	2.3	2	W-5&6	Navigation accuracy
11 Dec 72	301	1.3	1	W-5&6	Tower fly-by, throttle transients
11 Dec 72	302	1.6	1	W-5&6	Airspeed calibration, AFCS test
12 Dec 72	303	1.8	1	W-5&6	Tower fly-by and airspeed calibration
15 Dec 72	304	2.3	2	W-5&6	Navigation accuracy
18 Dec 72	305	1.3	1	W-5&6	Tower fly-by
18 Dec 72	306	1.7	1	W-5&6	Airspeed calibration, throttle transients
19 Dec 72	307	1.8	1	W-5&6	Tower fly-by and airspeed calibration
19 Dec 72	308	1.4	1	W-5&6	Airspeed calibration, throttle transients
11 Jan 73	309	2.1	1	W-5&6	Pitch rate transients turbulence test
31 Jan 73	310	2.4	1	W-5&6	Airspeed calibration, throttle transients
2 Feb 73	311	1.8	1	W-5&6	Tower fly-by, throttle transients
2 Feb 73	312	1.2	1	W-5&6	Airspeed calibration
12 Feb 73	313	2.1	1	W-5&6	Airspeed calibration
5 Mar 73	314	2.3	1	W-5&6	Head-up display, takeoff tests, Mode C checks
7 Feb 73	401	1.9	1	W-5&6	Tower fly-by
13 Feb 73	402	2.0	1	W-5&6	Airspeed calibration, throttle transients

¹Flight numbers correspond with the aircraft tested: 001 through 006 with A-7D 584, 101 through 149 with A-7D 973, 201 through 220 with A-7D 944, 301 through 314 with A-7D 338, and 401 and 402 with A-7D 351.

²Loadings are described in table I.

Total 91 flights 144.5 hrs

REFERENCES

1. Airspeed Calibration and Development of the AIMS Pitot-Static System on the A-7D Airplane, Technical Letter Report, Air Force Flight Test Center, Edwards AFB, California, August 1971.
2. DOD AIMS Preflight and Flight Test Procedures (Air Force), DOD AIMS Document No. 153, 15 February 1971.
3. Flight Manual, USAF A-7D Aircraft, T.O. 1A-7D-1, 15 November 1971, Change 6, 16 November 1972.
4. Jackson, Samuel G., et al., A-7D Category II Mission and Traffic Control Avionics Evaluation, FTC-TR-70-25, Air Force Flight Test Center, Edwards AFB, California, November 1970.
5. DeAnda, Albert G., AFFTC Standard Airspeed Calibration Procedures, FTC-TIH-68-1001, Air Force Flight Test Center, Edwards AFB, California, April 1968.
6. Telephone Conversation with Mr. Richard DeLeo, Rosemount Engineering Company, Minneapolis, Minnesota, 25 February 1972.
7. Jackson, Samuel G., et al., A-7D Category II Follow-On Weapons Delivery and Gunnery Evaluation, FTC-TR-71-19, Air Force Flight Test Center, Edwards AFB, California, May 1971.
8. Rider, James G., Major USAF, and Edwards, Lloyd A., Captain USAF, "Your New AIMS Telemetry System" in Aerospace Safety, November 1972.
9. Plews, Larry D., Preliminary Results of Pacer Accuracy Study, Flight Research Branch Office Memo, Air Force Flight Test Center, Edwards AFB, California, June 1969.
10. Meness, C.T., Procurement Specification for Air Data Computer System for A-7D/E Airplanes, Vought Aeronautical Division, LTV Aerospace Corporation, Dallas, Texas, November 1969.
11. Contract Specification for the AAU-19/A Altimeter, DOD AIMS 64-101D, undated.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Air Force Flight Test Center Edwards AFB, California		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
		2b. GROUP N/A	
3. REPORT TITLE A-7D Pitot-Static System Calibration and AIMS System Tests.			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final rept. 23 Feb 72 - 5 Mar 73, 112 p.			
5. AUTHOR(S) (First name, middle initial, last name) Jack H. Markwardt, Captain, USAF Samuel G. Jackson Karl M. Jones, Major, USAF			
6. PERIODICITY May 73		7a. TOTAL NO. OF PAGES 101	7b. NO. OF REFS 11
8a. CONTRACT OR GRANT NO.		8b. ORIGINATOR'S REPORT NUMBER(S) AFFTC-TR-73-18	
9. PROJECT NO. AFFTC [redacted] 71-17 APPTC-71-17D		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) N/A	
10. DISTRIBUTION STATEMENT Distribution limited to U.S. Government agencies only (Test and Evaluation), April 1972. Other requests for this document must be referred to Naval Air Systems Command, PMA-235B, Washington D.C. 20360.			
11. SUPPLEMENTARY NOTES N/A		12. SPONSORING MILITARY ACTIVITY Deputy Commander for Operations Air Force Flight Test Center Edwards AFB, California	
13. ABSTRACT This document contains the results, substantiating data, test techniques, and data analysis methods for the A-7D AIMS tests, Level 2 (Mode C) and Levels 3 through 5, for A-7D aircraft with boom refueling receptacles. The AIMS modification met the AIMS Levels 2 and 4 criteria. The AIMS Level 3 criterion was not met in the transonic flight regime. The Level 5 criterion was not met because the pitot-static system error was influenced by throttle setting during rapid descents at high Mach numbers, and large, rapid throttle movements caused erroneous transients in the altitude and vertical velocity indications. Angle-of-attack changes caused by turbulence or pilot pitch inputs resulted in rapid, erroneous fluctuations of the airspeed indicator, altimeter, and vertical velocity indicator. Further design and testing were recommended to improve the pitot-static system in the areas that did not meet the Level 5 criterion. This document also contains the results, substantiating data, test techniques, and data analysis methods for the Levels 3 and 4 tests on an A-7E aircraft with the air refueling probe. The discussion applies to aerodynamically similar A-7D aircraft with the air refueling probe. The AIMS modification for the A-7E aircraft with W-5 and 6 air data computer (ADC) cams (designed for A-7D aircraft equipped with boom refueling receptacles) did not meet the AIMS Level 3 criterion. Further pitot-static probe design and testing were recommended to develop a system with W-5 and 6 ADC cams that would meet the Level 3 criterion.			

DD FORM 1473

NOV 66

UNCLASSIFIED

Security Classification

012 / 100

mt

UNCLASSIFIED
Security Classification

14	KEY WORDS	LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT
	A-7D airplane pitot-static calibration AIMS system tests transonic flight pitot-static probe installation/location throttle setting effects barometric pressure bombing using AIMS Level 3 error analysis						

UNCLASSIFIED
Security Classification